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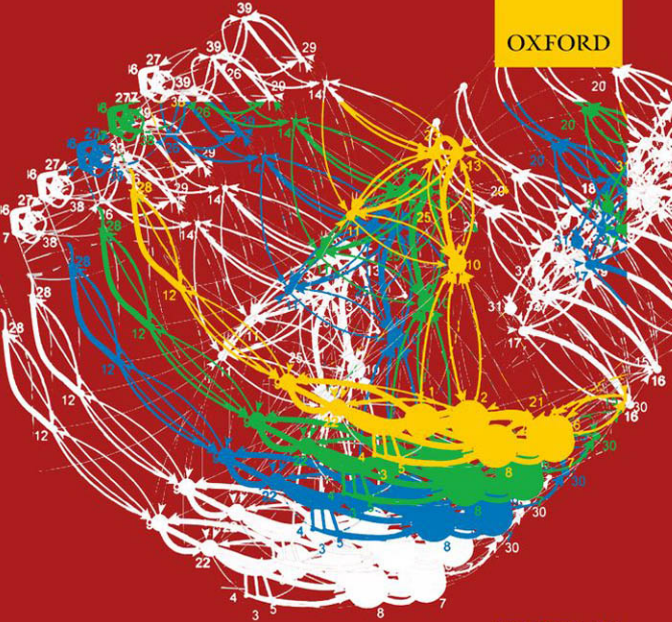

EDITED BY
CARL KNAPPETT

# Network Analysis in Archaeology

*New Approaches to Regional Interaction*

NETWORK ANALYSIS IN ARCHAEOLOGY

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*New Approaches to Regional Interaction*

*Edited by*

CARL KNAPPETT

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# Part I

# Background

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# 1

# Introduction: Why Networks?

*Carl Knappett*

## 1.1 NETWORKS: METAPHORS AND METHODS

'Network' is not a new term in our discipline. Archaeologists have for some time written of exchange networks, interaction networks, and road networks. Such usage is fairly generic, however; the kind of usage we make of 'network' in everyday speech. It is little more than a handy metaphor for connectivity. So why now should we see a volume on networks? The reason is that a quite different understanding of 'network' is emerging, one that goes a step further to ask what a network actually is. In its basic definition, it is nothing more than a collection of nodes and links. But this simple step, of acknowledging the network as having some basic formal properties, then opens doors. Once considered as a set of nodes and links, the next step is to define what those nodes and links actually are. Are the nodes the households in a village, and the links between them ties of marriage? Or are they a set of sites in a particular region, and their links the shared use of a particular resource; say, obsidian?

This step—to ask in more formal terms what a network is—is exactly the one taken by all the authors in this volume. Each uses some form of network analysis in tackling their own particular dataset to address questions concerning patterns and processes of interaction in past societies. As can be seen from the assembled chapters, there is an extremely broad range of places and periods where network analysis is underway, from Japan to the US Southwest, and from the Palaeolithic to the Precolumbian. This diversity is potentially extremely fruitful, but there is also the risk that without dialogue these diverse takes on networks in archaeology could lead to a fractured field of study. The explosion of network analysis in the past decade across such diverse fields as sociology, physics, and biology has created a vast array of options, which archaeologists, exposed to different influences, have been picking up on rather haphazardly. Again, this diversity could be beneficial; or it may just create another ironic example of the poor networking among network approaches

(Knox et al. 2006: 114). Hence this volume is an attempt at networking our different network approaches.

One of the features uniting the approaches here is the focus on the regional scale, although the chapter by Mol and Mans shows that networks can be analysed at more intimate scales too. Whatever the scale, we do need to think carefully about how we define the nodes and links in a given network. Should every settlement in a region be considered a 'node'? If so, should we differentiate between different kinds of 'nodes', large and small, or perhaps according to site function? What about the links—how should these be defined? Generally in archaeology very little thought has been given to links: archaeologists will usually satisfy themselves with distribution maps that have lots of nodes marked but no links whatsoever. What do we gain from depicting links, in terms of directionality, frequency, and fidelity, for example? Where does the power of network analysis lie? In the capacity to span and articulate different scales of analysis, from micro to global; in its potential for integrating both people and things; or in its scope for mediating between social and physical space? Or more simply, is it a heuristic for stimulating ideas about links and relations and not just nodes and entities? These are just some basic questions for network thinking that need to be asked across different contexts. What we'll see in this volume are quite different definitions of what constitutes a node and a link—and it is important that we explore these differences. Furthermore, the kinds of analysis performed are not all the same, ranging from centrality measures, to community detection, to characterizing weak/strong ties.

However, it is too simplistic to argue that network approaches have only been current in archaeology within the past decade. We could trace their use back to David Clarke (1972, 1977) and the New Archaeology, itself influenced by the New Geography (e.g. Haggett and Chorley 1969); and then island biogeography approaches in Oceania (Terrell 1977; Hunt 1988; Terrell 1977). In the intervening years, network applications in archaeology have been few and far between, with the occasional exception, as in work on Cahokia (Peregrine 1991), or Inka roads (Jenkins 2001). What quickly becomes apparent in a brief review is that network analysis never quite gets going, not even in GIS approaches.

## 1.2 NON-NETWORK APPROACHES

It is possible to imagine that for some archaeologists, networks may seem overly structural and rigid, without sufficient possibility for paying attention to agency. With agency high on the agenda in the rise of post-processual approaches in the 1980s and 1990s, this could form some sort of explanation

for an aversion to networks. However, many archaeologists during this period were still very much interested in more 'processual' themes, such as interregional interaction (Schortman and Urban 1987). And although Schortman and Urban do use the term 'network' with some frequency, there is no real mechanism of network analysis employed for addressing network properties. The lack of uptake of network analysis is therefore quite difficult to explain, given its considerable advantages over comparable approaches that have dominated this sub-field. Let's take one of these approaches: world-systems theory/analysis. This was attractive to archaeologists because it offered a clear explanatory role for intercultural contact in cultural change, and it embedded the study of trade within the broader phenomenon of 'interaction' (Bauer and Agbe-Davies 2010: 39). There are all kinds of modifications and applications of one kind or another in many different areas and periods (Kardulias and Hall 2008), testament to its broad appeal. However, most applications share one key problem: they are aimed squarely at intersocietal and not intrasocietal dynamics (Stein 2002; Bauer and Agbe-Davies 2010: 40). Even though Stein sees some possibility for articulating it with more post-processual concerns such as agency and ideology, and Kristiansen and Larsson (2005) have sought to create a multi-scale interactionist approach, there is very little scope in fact for bringing a form of analysis so evidently aimed at one scale down to other scales. The name itself gives it away: world-systems.

Another problem of world-systems theory is the core-periphery assumption. Stein (2002) critiques this for having a 'misplaced directionality' (see also Bauer and Agbe-Davies 2010: 40). This is indeed a major problem. But there is a still more serious limiting assumption it shares with many other interactionist approaches: that of the 'zonal' (or 'blob' in Smith's words!) approach to regional space. This implies that influence/resources radiate out from locations uniformly. This is an assumption widely made in archaeology that brings all kinds of corollary problems (Smith 2005; Jennings 2006; Chapter 6 in this volume).

Still, world-systems theory was in many ways an improvement on what had come before, in that it did provide a theoretical framework for understanding the role of intercultural contact in culture change. In contrast, New/processual archaeology had seemed to either (a) focus primarily on local, endogenous processes as the motor for change, in an evolutionary framework, and hence not consider intercultural contact at all (Bauer and Agbe-Davies 2010: 31), or (b) take an overly formalist approach to such contact, underscored by its scientific, quantitative work on sourcing and provenance, as for example in Renfrew's obsidian sourcing work in the Mediterranean (Renfrew 1975; Bauer and Agbe-Davies 2010). Exchange was a key focus in a range of other settings too, such as the US Southwest (Plog 1977), and Mesoamerica (Sidrys 1977), these studies forming part of influential edited volumes on exchange (Sabloff and Lamberg-Karlovsky 1975; Earle and Ericson 1977; Ericson and Earle

1982). While such work made important advances in the archaeological methods for tackling inter-regional exchange and interaction, this impact was perhaps diminished by the distracting debate between formalist and substantivist approaches (Oka and Kusimba 2008). What Renfrew and colleagues were actually doing was identifying some of the actual patterns, and in some cases processes, whereby materials moved between regions. This in some senses continued the fascination in cultural history approaches with intercultural contact, with Childe in particular showing incredible range in identifying cultures all across Europe and the Near East and the apparent 'diffusion' of cultural traits between them. However, the recognition of intercultural contact and influence that formed the basis of much archaeological thinking in the early 20th century was not matched by a firm grasp of the actual processes and motivations involved. Critics found 'diffusion' to lack any explanatory power and hence the emergence of more process-driven approaches, of which Renfrew's work, mentioned above, is a good example.

Yet however far archaeology may have come since the diffusionism of culture history, there remains in many approaches a lingering notion of its 'radial', or 'zonal', approach to regional interaction. We see it still in the core–periphery assumptions of world-systems theory, as mentioned above. New approaches to inter-regional contact and exchange, such as Oka and Kusimba (2008), or Bauer and Agbe-Davies (2010), recognize some of the existing limitations in exchange/interaction studies, and bring renewed theoretical vigour to the idea of studying exchange. But an accompanying drive for new integrated methodologies eludes them. This may seem curious given the apparent suitability of many techniques in GIS for tackling interactions in space. However, GIS is only as good as the assumptions we generally bring to our archaeological/geographical understanding of space: if we think in terms of points and radial zones, then GIS as a tool will simply reproduce these assumptions, albeit with a sophisticated overlay (see Doel 1999, Batty 2005, on GIS as basically a point-based approach).

## 1.3 NETWORKS NOW

Network approaches can avoid many of these problems. They do not bring necessary directionalities. They do not oblige the drawing of boundaries, zones, or territories based on limited information. They can be relational and/or spatial, so they do not succumb necessarily to the criticism of either spatial or social determinism (note, Smith 2003 on relational and geometric space). And most importantly, they can cross scales. Anything from a household to the state can be thought of in terms of a network (Knappett 2011). We also do not need to reinvent whole new methodologies: GIS, for example, is

perfectly capable of supporting the network approaches that can move us away from territorial assumptions and point-based models towards more relational, multi-scale perspectives.

And what we are seeing now, arguably, is a concerted use of network analysis for some of these very reasons. There are many possibilities for network analysis that have barely been explored in archaeology (Brughmans 2010). Nonetheless, the turn to networks underway is quite a marked development. Why now, and why in this form?

Seeking an answer to these questions reveals an interesting paradox. On the one hand, archaeologists are surely no more immune than any other member of the general population to the wave of publicity surrounding advances in physics and complexity science, driven especially by the breakthrough paper on 'small worlds' by Duncan Watts and Steven Strogatz (Watts and Strogatz 1998), with subsequent popular science treatments (e.g. Watts 2003; Barabási 2002). This is of course caught up in the expansion of the World Wide Web, and the fascination with social networking sites and technologies such as *Facebook* and *Twitter*. On the other hand, it is not these kinds of treatments of networks at the hands of physicists that are guiding archaeologists in their actual network research. Some exceptions apart (Bentley and Maschner 2003; Knappett et al. 2008; Evans et al. 2009), most archaeologists, as indeed can be observed in this volume, use the insights of Social Network Analysis (SNA), a field of research in sociology that has been well-established since the 1970s (e.g. Granovetter 1973; White et al. 1976; Freeman 1977; Wasserman and Faust 1994; Carrington et al. 2005). Thus the turn to SNA only in the last five years or so is curious, given that it has been there all along, so to speak. It is possible that the buzz surrounding networks generated by work in physics/complexity science inspired archaeologists to turn to networks, who may have found the sometimes complex maths beyond their social science training; and then encountering SNA in this process of exploration, they found something more amenable.

We should not be too surprised, though, at the relative lack of awareness of SNA previously in archaeology. Historically, there has been very little overlap between sociology and archaeology; during the great theoretical debates of the 1960s and 1970s, the cross-disciplinary reference points and sources were primarily anthropology and geography (note some use of networks in these disciplines, particularly the New Geography, Haggett and Chorley 1969; and in anthropology, Barnes 1954, 1972; Mitchell 1974, for example).

SNA is also not necessarily an obvious fit for other reasons. First, sociologists analyse networks with links that they can more or less fully reconstruct—the friendship ties in a school, or the ties that link business directors to one another via shared positions on directorial boards. Once these ties are documented, the sociologist can proceed to analyse the structures of the networks involved. For the archaeologist, however, these links are generally absent: we

have to reconstruct them. This is precisely the point that Søren Sindbæk makes in his chapter—we are engaged not so much in network analysis as network reconstruction, or what he dubs network *synthesis*. Secondly, SNA concerns itself mostly with relational networks, with geography very much a secondary consideration. This again does not sit particularly comfortably with archaeology, as most archaeologists working on networks find it hard to avoid locating their network nodes first and foremost in physical space. Thirdly, as can be seen in the papers in this volume, archaeologists include material culture as a critical component in their networks, often defining links between nodes on the basis of shared material culture attributes or the movement of commodities from one to another.

SNA may have fewer equations than physics, and *seem* more immediately accessible, but this does not automatically make it the better solution for archaeologists seeking network methods. Indeed, approaches derived from physics/complexity science hold some considerable advantages. First, though they too have been rather 'despatialized', there are approaches now really addressing geographical space with increasing effectiveness (see review in Barthélemy 2011; and note compatibility with GIS). Secondly, they are now getting to grips with time evolution in interesting ways, with dynamics of networks over time a hot topic (e.g. Mucha et al. 2010). Thirdly, they can develop ways to work with embedding material culture links. There is of course a danger of getting carried away with the technical possibilities, and failing to address substantive *social* questions effectively; after all, physicists are not social scientists. And with some justification some have come under fire from SNA sociologists for not giving due credit to the much longer history of SNA work on networks (e.g. Scott 2011). This does seem to be a real problem of disciplinary boundaries, as Scott points out with research showing the lack of mutual citation (though do note bridge-building efforts in Watts 2004). Certainly SNA has a depth of questions and answers it has accumulated over decades of research that should not be taken lightly; and on the other hand, network science can bring new tools to the table, and inevitably new questions and insights too. Although some serious barriers exist, there are reasons to be positive, and archaeology can, perhaps surprisingly, be a useful bridge between the two.

When all this is said and done, perhaps more important than the source of inspiration is how archaeologists have been putting networks to work. Principally they have been used as an *exploratory* method. This emerges very clearly in the contribution in this volume by John Terrell, who argues that the great advantage of SNA for archaeology is its capacity to provide a set of exploratory techniques for data analysis. This is echoed in the chapter by Leif Isaksen identifying three themes in network analysis in archaeology, all of which have this exploratory character: visualization, metrics, and experimentation. He provides brief case studies from archaeological projects that serve to illustrate

each of these themes. Isaksen suggests, however, that the inspiration for archaeologists has come more from network science than from SNA. Søren Sindbæk in the following chapter also then argues for networks that 'their true importance is as a tool to test and explore properties of complex datasets'. To this he adds that network techniques are also a means of demonstrating patterns and hence providing a level of *validation* to results obtained by other means. Sindbæk goes on to contrast the process of network exploration in archaeology to that commonly seen in SNA. In explaining his point concerning network analysis versus network synthesis, as mentioned above, he likens the archaeological process to one of working with black boxes—one might know some of the inputs and outputs, but the actual network, or circuit-board so to speak, remains hidden within the 'black box'. So whereas social network analysts know in advance the shape of the network they study, for archaeologists this is the very challenge, to try and discern the shape from material remains of inputs and outputs. In a sense, then, he argues, archaeologists may be better off taking guidance from work in network design optimization, which works with these kinds of 'black-box' problems, rather than SNA. So whether drawing on SNA, network science, or network design optimization, what seems common to all is the desire among archaeologists for techniques that do not need to presuppose too much theoretically, as Terrell argues is the case for Darwinian, phylogenetic approaches. Perhaps it is this search for a bottom-up methodology whereby one can find structure (together with agency—see Scholnick et al., this volume) that is key to explaining its emergence now.

Other key themes that emerge in these and subsequent chapters are time, geography, and material culture. In the chapter on the nature of Classic Maya political authority, by Jonathan Scholnick, Jessica Munson, and Martha Macri, we see the application of techniques of blockmodelling from SNA for community detection. They focus on the ways in which Maya polities position themselves relative to one another, as discerned from statements of political affiliation on stone monuments. They are able to demonstrate the existence of distinct communities or 'blocks' of political affiliation, whereby certain polities associate themselves with one another through various means, sometimes diplomatic, sometimes bellicose. One particularly interesting result is how these groupings do not simply reflect geographical proximity; political links seem to be made, or at least claim to be made, with polities 20 to 70 km away.

In the next chapter by Ray Rivers, Tim Evans, and myself, we use techniques from physics to interrogate some of the principal ideas from SNA used in archaeology; namely, centrality. As we are concerned with networks in physical as well as social space, our treatment of centrality does have a geographical component. We argue that it is important to differentiate between networks that are unweighted and undirected, and those that are weighted and directed. In the former, links of equal strength are either switched on or off, as in

citation networks. This is not the case for most kinds of ancient social networks with which archaeologists are generally concerned: we will tend to see strong links and weak links, and links that are stronger in one direction than the other. So given directionality, it becomes significant how one ranks a site, by inflow or outflow. A 'busy' site, with high inflow or outflow, can be said to have high rank, regardless of its size. When rank and size are combined, one can talk of 'impact'—so a site with a large population and high rank will have high impact. There are all kinds of measures of centrality based on rank and impact—but what we set out to do is find ways of understanding what features might dynamically *generate* centrality on networks. After discussing some null models—geographical networks, PPA, and simple gravity models, in the sense that all assume undirected links—we turn to models that accommodate gravity while being directed, and which hence can be dynamic. After critiquing the Rihll/Wilson model, based on urban retail models to define the most suitable locations for shopping malls, i.e. those that will best draw in all the 'outflow' of their neighbours, we present as more appropriate the 'ariadne' model, which uses a cost-benefit function to arrive at 'efficient' networks. This is a useful tool allowing us to model how centrality might be emergent in socio-spatial networks.

In the following chapter, Koji Mizoguchi uses SNA, and particularly centrality measures, to compare and contrast two instances of hierarchization in the Japanese Yayoi and Kofun periods, *c.*600 BC–AD 250 and AD 250–AD 600 respectively. Both scenarios witness the emergence of large regional interaction spheres in which prestige goods circulate, and some sites become central in interaction networks. In the Yayoi period, what the network analysis shows is that the first-tier sites were not necessarily those enjoying the position of highest centrality. In the Kofun period, however, the top sites do reflect network centrality. Mizoguchi suggests that the better fit of the Kofun hierarchy with the topological structure of the network can in part explain its relative stability, in contrast to the preceding Yayoi network, which indeed collapsed. He further argues that the Kofun prestige-goods system was more mature, founded on internal features, whereas the 'primitive' Yayoi system was always vulnerable to external forces; in particular, its reliance on products from the Han empire. So Mizoguchi's treatment is dynamic, linking the temporal stability of social hierarchies over time to their underlying topological structure.

The contribution from Barbara Mills and collaborators also makes use of archaeology's capacity to look at network evolution over the long-term. They take fifty-year snapshots of the US Southwest between 1200 and 1400 AD, drawing on a huge database of over 1600 settlements and *c.*4.4 million ceramic artefacts. They create networks by linking settlement nodes according to shared ceramic artefacts. Two regions are selected as case studies, the San Pedro Valley and the Tonto Basin, and the eigenvector centrality of sites in the two areas is compared. In the San Pedro Valley, first-comer villages maintain

high centrality throughout the 200-year period, while in the Tonto Basin, sites that were central early do not remain so—here centrality did not guarantee persistence. It seems that the dynamics of migration played out differently in the two areas, an elegant example of how SNA can be sensitive to historical circumstance.

The strengths of a diachronic approach are also clear to see in Emma Blake's chapter. She adopts the notion of 'path dependence' to investigate the long-term factors at work in the emergence of distinct ethnic groups in Pre-Roman Italy. Critiquing existing explanations of these regional groupings as simply either primordial or instrumentalist, Blake develops an interactionist model that sees ethnic group formation arising out of social interactions. Furthermore, with incremental investments over time in particular patterns of interaction, it may be that at some juncture it becomes prohibitively costly to change paths, and so the same patterns and structures are maintained—the idea of path dependence. Blake suggests that if this is the case, we should perhaps look back much further in time than has commonly been attempted, and seek the roots of Iron Age ethnic group formation in the Bronze Age. Aspects of Late Bronze Age (LBA) regional interactions can be proposed on the basis of shared consumption of specific imported artefact types, namely Mycenaean pottery, amber beads, and bronzes. Blake argues that already in the LBA there are groups of sites favouring each other in exchanges, and that the network structure seems to presage the position of later Etruscan and Latin groups. In the LBA, then, Blake maintains, 'west central Italy already exhibits the internal divisions that characterize its subsequent history'.

This theme—identifying the emergence of ethnic groupings—is also the subject of the chapter by Anna Collar. Her case study concerns the structure of the Jewish diasporic network and the conditions of its development following the catastrophic events in Judaea in the 2nd century AD. In the epigraphic evidence Collar notes a 'massive increase in explicit statements of Jewish identity from the second century onwards'. She interprets this in terms of changing interpersonal bonds between Jewish communities, with the activation of a strong-tie network spanning long distances. This network was used to transmit the reforms of rabbinic Judaism. Using proximal point analysis, Collar is able to identify aspects of network structure. She uses timeslices—1st–2nd centuries AD, 3rd century, 4th century, and 5th–6th centuries—as a means of approximating the diachronic development of these diasporic networks. What this shows is the increasingly centralized nature of the network over time, heavily directed towards Judaea. The importance of long ties in these networks is an interesting corrective to the 'strength of weak ties' that we often read in the network literature.

In the Roman period studied by Anna Collar, there were very few infrastructural or transport limitations on intense long-distance interaction. But in the material presented by Fiona Coward in her chapter on the Near East, we

encounter a very different prehistoric scenario—the transition in the Near East from hunter-gatherer to farming societies, from 21000 to 6000 BCE. Like Collar, Coward uses timeslices to approximate evolution over time and provide some sense of the very long-term dynamics of social networks. Unsurprisingly, with the size of social groups and transport technologies available, here Coward does find that as the geographical span of social networks increases, so those networks become ever more fragmented. This seems to fit with the notion of weak ties as crucial connectors *between* groups. Yet *within* more localized regional networks, there is not a tight relationship between geographical and social proximity. An interesting perspective that Coward brings is to treat material culture not simply as a proxy for social interactions, but as an integral part of them, so that the increasingly widespread links between groups are actually facilitated and enabled by material culture (see also Gamble 2007; Knappett 2011). By combining the active role of material culture, a long-term diachronic perspective, and an explicit consideration of the articulation of geographical and social distance, Coward raises many of the main themes with which archaeologists are grappling in their nascent network work.

The approach adopted by Gjesfjeld and Phillips is more sceptical and has connections with that of Sindbæk—that if we are to make headway with archaeological network analysis, we need to confront head-on what Sindbæk calls the 'black-box' problem. That is to say, how do we reconstruct the network 'circuit-board' when we can only view the inputs and outputs? They decide upon an approach that involves establishing a set of generalized models against which one can assess how well a particular dataset fits. They propose three models—local production with limited exchange, local production with reciprocal exchange, and central place production with redistribution exchange—each of which comes with certain expectations in terms of their network properties. When they set about testing their own archaeological data, from interaction networks in the Kuril Islands based on ceramic data, they conclude that there is no good match with any one of these models. In their view, this indicates that more work is needed to establish more firmly the links between archaeological data patterns and the likely mechanisms that generated them, as traditional models of exchange are insufficient.

In the penultimate chapter, Angus Mol and Jimmy Mans take a novel approach that works between an ethno-archaeological study of intra-community network dynamics, and an archaeological analysis of inter-community network patterns, both in the indigenous Caribbean. Their argument is that we can misinterpret the inter-site networks if we do not pay sufficient attention to the underlying intra-site dynamics. This is a very useful reminder that, although in this volume we have chosen to focus on regional interaction networks, there are other scales at which social connections need to be explored. Indeed, network approaches do allow for nested, multi-scalar analysis, and this is a feature that does need more investigation of the kind offered here by Mol and Mans.

Finally, in an invited discussion chapter, Sander van der Leeuw considers the themes emerging in the volume and places them within a broader social science context. He identifies the *emergence* of networks as a key research focus—and the concomitant need for a forward-looking perspective that can capture the very conditions of emergence, rather than an 'ex post' viewpoint that can only see change once it has happened. Indeed the diachronic dynamics of networks are only now receiving the attention in network analysis that they patently demand. And if we can succeed in approximating the temporal development of a network, then we may then begin to see, van der Leeuw argues, how different kinds of networks differentiate themselves over time and gradually become interrelated in complex ways. He makes the important point of the need to acknowledge the multiple forms of networks, using a fundamental distinction between information, energy, and matter. Networks as they become optimal are very often hierarchical, and this is a property that could perhaps be better investigated in archaeological approaches. Although the network has been a useful tool for avoiding the need to assume hierarchy a priori, this does not mean that our networks should be flat when hierarchy is indeed present.

## 1.4 CONCLUSIONS

All the contributions in this volume make explicit use of network models, and the majority from SNA. Many deal with themes that are not a particular strength of SNA, such as dynamic time evolution, geography, and material culture. There are ways of making more use of the powerful techniques of network science, at the risk of moving away from the social questions that ought to be primary; and at the other end of the spectrum, there are those more firmly embedded in the humanities making use of network ideas more figuratively (Malkin 2011). We probably need to work between both ends. I think these chapters are well situated between these different traditions, sometimes positioned antagonistically, and that archaeology can indeed play a bridging role, bringing some of its traditional strengths to bear on network issues: spatiality, temporality, and materiality.

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# 2

# Social Network Analysis and the Practice of History

*John Edward Terrell*

I am going to assert, but within the narrow confines of this chapter cannot prove, that archaeologists spend too little time on the practice of history. Instead, they often take it for granted that the results of their efforts and formal analyses contribute more or less directly to historical understanding with scant attention to E. H. Carr's famous question *What is history?* (Carr 1961). Some nowadays actually say that their analyses are showing us that certain 'macroevolutionary' historical processes govern (and therefore explain) who we are and what we do, and that human history, like Darwinian biological evolution, is basically about 'descent with modification' (Steele et al. 2010), a notion that would surely have perplexed Carr who is still well-regarded by fellow historians as the author of a fourteen-volume history of the Soviet Union. Other archaeologists similarly embrace the idea of evolution, but devote their energies not to the statistical construction and certification of phylogenetic trees of Turkmen textiles (Tehrani et al. 2010), projectile points (O'Brien et al. 2011), and so on, but instead to substantiating their claim that human history is about the evolution of something called complex societies (Chapman 2003; Marcus 2008).

Both of these ways of thinking and writing about history may have much to recommend them. Yet both strike me as narrow, confining, and arguably doctrinaire. However, it is also obvious that there is no single universal answer to Carr's famous question since there are many different kinds of histories. Furthermore, Carr's published answer to his own question comes across today at least to me as crafty, circular, and too easily lampoon-able as 'history is what historians write'.

Even so, there is little doubt that history for Carr was about people and their acts and intentions, not about things like projectile points or knotted rugs. 'I think we are entitled by convention', Carr insisted, 'to reserve the word "history" for the serious process of enquiry into the past of man in society' (1961: 59).

Archaeologists who are dedicated to drawing phylogenetic trees or showing that history moves as Herbert Spencer (1857) said it did from the simple to the complex would undoubtedly insist that they, too, are just as interested in the past of man in society as any historian alive or dead except that, being archaeologists, they must largely work with what they dig up or find in the rug bazaar. So the only real difference between someone like Carr and the average archaeologist is that the latter is able to learn about people, motivations, and deeds only third-hand while historians can do so second-hand from the first-hand accounts of eyewitnesses, published and unpublished written memoirs, tax records, and the like.

This defence against the retort that a history of projectile points however phylogenetic sounds more like a history about projectile points than about people seems logical. However, maybe the question *What is history?* is not asking what really needs to be asked. If history is taken to be about the past of people in society, then just below the surface of Carr's classic question is an equally demanding one: *Whose history are we writing?*

Although making rugs or projectile points may normally be the work of individuals, archaeologists generally say that they do not write about the history of individuals, but rather about the history of collective entities variously labelled as cultures, societies, polities, chiefdoms, states, and the like. But is the history of such corporate entities what Carr meant by the history of man in society?

Many archaeologists certainly have no qualms about shifting the focus, or scope, of their practice of history from the generic level of 'man in society' to the particular study of the history and characteristics (and evolution) of 'societies'. After all, doesn't common sense tell us that different kinds of people inhabit the earth? If so, shouldn't we be able to identify and classify them, and then write their history, ancient or modern (Terrell 2001b)? Haven't archaeologists for generations been detailing and documenting variation in material culture across space and time specifically in hopes of pinning down and comparing societies, or 'social groups', that are supposedly identifiable as such because they have boundaries marked by distinctive patterns in the archaeological record (Stark 1998)? Isn't the premise behind this research goal that 'people have always defined themselves in terms of material culture differences (including technology) and that part of that definition involved group identity' (Hegmon 1998: 274)?

However convinced many archaeologists may be that the correct answer to each of these four questions is 'yes', I think the practice of writing history this way in archaeology is a fine case of putting the cart before the horse. Rather than having to assume beforehand that archaeologists can and must identify socially bounded human collective entities in the past (e.g. social groups, societies, chiefdoms, and states), what is needed are ways for archaeologists to discover what the patterning of cultural variation in the past may tell us

about how people lived without having to presuppose that they lived not just in *society*, but in archaeologically identifiable *societies*.

With this need in mind, I suggest that modern social network analysis (SNA) is both a body of theory and a set of relatively new computer-aided techniques used in the analysis and study of relational data ideally suited to such an analytical and interpretative objective.

## 2.1 SOCIAL NETWORK ANALYSIS (SNA)

It has become widely accepted that modern SNA as a research strategy or paradigm has at least four principal characteristics (Bernard 2005: 377):

1. the focus of research is on ties between people (called 'actors') rather than on the attributes of actors;
2. SNA is grounded on the systematic collection of data about those ties;
3. there is a strong emphasis on the visual, or graphical, presentation of research results; and
4. because information about social ties can often be voluminous, computers and computational approaches to data analysis are usually necessary, even critical, to the success of SNA studies.

Histories of the subject usually say that modern SNA became a successful research paradigm in the social sciences when Harrison White started teaching the subject at Harvard University in the mid-1960s (White 1965). It is generally stressed, however, that a number of different threads have shaped the development of what is now called SNA (Scott 2000).

One of these threads is mathematic graph theory (Harary et al. 1965). In the Pacific, for instance, the anthropologist Per Hage teamed up with the mathematician Frank Harary to apply graph theory to patterning in the social world of Pacific Islanders (Hage 1977; Hage and Harary 1981, 1983, 1986). As Hage pointed out in 1979: 'Graph theory is a branch of mathematics concerned with the analysis of structures consisting of points joined by lines .... An important advantage of graph theory, which largely accounts for its intuitive appeal, is that it contains a means for the depiction of structure' (Hage 1979: 115). Few scholars working in the Pacific found much of interest in this claim, and the impact of graph theory on scholarship in this part of the world was negligible. As a methodology, graph theory looked not only formal but formidable, and the specific applications offered in several publications by Hage and Harary seemed to many of us at the time like belaboring the proverbial elephant to deliver a mouse (Kronenfeld 1986).

Also in the Pacific in the 1970s and 1980s, what SNA researchers call a small social circle or clique (Knoke and Yang 2008: 72–6) of archaeologists

comprising Geoff Irwin at the University of Auckland and the Australian National University, Terry Hunt at the University of Washington, and myself at the Field Museum in Chicago, began to develop and apply simple graphical network techniques to archaeological problems (Hunt 1987, 1988, 1989; Irwin 1972, 1974, 1977, 1978, 1983; Terrell 1974, 1976, 1977, 1986). This research focus had developed apart from the SNA tradition then beginning to flourish at Harvard and elsewhere, and we drew our inspiration largely from locational geography (e.g. Doxiadis 1970, Haggett 1966), island biogeography (MacArthur and Wilson 1967), and human population genetics (e.g. Coleman 1977; Fix 1978; Fix and Lie-Injo 1975).

Pointing out that my own interest in SNA developed more or less in ignorance of what was going on in the Harvard Department of Social Relations (when I was at Harvard during the 1960s, I spent my time in the Peabody Museum down the street from the building where this department was housed) is relevant to what I will be saying here about using SNA in archaeology. It is almost a cliché in modern SNA to comment that the focus of such research is on the patterning, or structuring, of human relations between persons or groups, and not on the attributes and attitudes of the individuals involved. As Mark Newman (2010: 36), a leading theoretician in the field, explains: 'Social networks are networks in which the vertices [the points of connection] are people, or sometimes groups of people, and the edges [the lines connecting them] represent some form of social interaction between them, such as friendship.' Since archaeologists obviously cannot directly observe or quantify either edges or vertices of human relations in the past, they must deduce, or derive, both from the observable attributes of the residual evidence available to them, be it potsherds, textile fragments, projectile points, or whatever.

Given their remove from the former social realities they are trying to reconstruct, before using SNA methods to address research issues of interest to them, archaeologists must resolve a nested set of elementary questions:

1. What human activities might account for the archaeological evidence being analysed?
2. Which of these activities are relevant to the actual questions about the past held to be of interest?
3. Which subset of these relevant activities would have involved interactions of one form or another in the past between people locally or farther way?

These may appear to be obvious, even pathetically simple-minded, questions. However, they illustrate one of the great strengths of using SNA in archaeology. SNA is a set of *exploratory techniques for data analysis*, not a predetermined view of history programmed into the analyses done by the computational methods employed.

In this regard, SNA is different from contemporary phylogenetic approaches in archaeology. No assumptions need be made beforehand about the grand patterning of human history. Hence SNA methods are flexible tools for data analysis, unlike current phylogenetic 'descent with modification' approaches that ask us to accept not only the perfectly reasonable proposition that 'overall, for a variety of reasons, people tend to imitate others when acquiring cultural traditions rather than invent new skills and practices entirely by themselves, generating a tendency for historical continuity in cultural traditions, rather than radical change' (Jordan and O'Neill 2010: 3875), but also that 'new human groups are often formed by the splitting of a population to form daughter populations in a manner that is analogous to biological speciation' (Currie et al. 2010: 3904).

## 2.2 EXAMPLES

I offer you two worked examples. Each uses SNA to explore the patterning of human diversity in the south-west Pacific. Both are brief commentaries on research work published in 2010 in the *Journal of Island & Coastal Archaeology* (Terrell 2010a) and *Annals of Human Genetics* (Terrell 2010b). For details, I ask you to consult these two journals.

### 2.2.1 Language and Culture on the Sepik Coast

The *Yearbook of Physical Anthropology* in 1975 published a research report by Joel Fagan, then an undergraduate in anthropology at Northwestern University, and myself that examined among other things the empirical and statistical weaknesses of the claim that certain genetic markers first identified biologically in 1956 could be used to distinguish people in the Pacific who speak languages belonging to the Malayo-Polynesian, or Austronesian, linguistic family from people speaking languages of that other great grouping of tongues in the Pacific, the supposedly older Papuan, or non-Austronesian, languages (Terrell and Fagan 1975). We concluded instead: 'there appears to be no evidence that Melanesian Austronesian-speakers taken as a group can be distinguished from Papuan-speakers, also taken as a group. Biologically, it continues to look as if the so-called Papuan and Melanesian peoples are nothing more than fictions created by linguistic taxonomy' (1975: 8).

Our report had originally been presented before a plenary session in Denver that year during the annual meetings of the American Association of Physical Anthropologists (AAPA). What we had to say later made us very unpopular in some scholarly circles. A few people would not even speak to me after the

plenary gathering. Indeed, the renowned physical anthropologist Sherwood ('Sherry') Washburn, who chaired the session, told the audience immediately following my presentation: 'Well, at least we now know who the savage is'.

What was at stake that drew such a dramatic response was an idea that had for generations been governing how the history of the Pacific Islanders should be written. It was taken for granted that the peopling of Oceania was a story about ancient migrations (Terrell 1990). To be sure, precisely how many human migrations there had been out into the Pacific was much debated. But everyone agreed that the minimum number had to be two. One great migration gave the region its non-Austronesian speakers; the other, its Austronesian speakers.

Recent molecular genetics research has established that Fagan and I had been right in 1975 to say that this sort of history is not just an inadequate accounting of Pacific history, but a fictional one (Soares et al. 2011). However, there were numerous attempts by many researchers after the Denver meetings of the AAPA to show how wrong and simple-minded Joel and I had been to dismiss linguistic taxonomy as a reliable road map to history—or as two critics in the mid-1990s declaimed, how 'unduly pessimistic' it is to say so (Moore and Romney 1994: 388).

Here are a few general facts. More than 2,000 languages, about one-third of all those spoken today on our planet, are spoken in the Pacific. About 250 of these are (or were) unique to Australia. Another 1,260 or so languages are classified by linguists as all belonging to one huge language family labelled nowadays as *Austronesian*, although many still know them under their old name, *Malayo-Polynesian*. Add all these languages together, and you arrive at an impressive number. But then also add in the 800 or so languages labelled by linguists as the *Papuan* or *non-Austronesian* languages spoken on New Guinea and on several other islands to the east and west of there. This is a lot of languages.

New Guinea has a land area of about 808,000 km$^2$. Narrowing the scope to New Guinea, the sum of both the Austronesian and the non-Austronesian languages in use in this part of the world totals around 830–850 languages. This is not the whole story. These languages are also unbelievably diverse, not only in numerical count, but also in kind. There are approximately twenty-four separate language families, all of which appear to be wholly unrelated to one another historically. There are also a handful of additional nine to ten languages that are unique in and of themselves, and thus stand alone as linguistic isolates. Eighteen Papuan families are represented on the New Guinea mainland. According to the linguist Andy Pawley (2005: 7), the most spectacular linguistic diversity, unmatched anywhere else in the world, is found in northern New Guinea where there are no fewer than fifteen unrelated families plus several isolates.

Why such language diversity? It is my experience that as soon as anyone hears about the number of languages spoken in the New Guinea area, they immediately

volunteer that people there must be really, really isolated from one another. After all, the idea that *divergence = isolation + mutation + time* is perhaps the most elementary way of thinking about the biological evolution of diversity, and basically the same elementary formula is how linguists also often describe the evolution of language diversity—except that they are less likely to use a word like 'mutation' to talk about something as close to home as language.

The sticking point, however, is not that change or mutation happens in language as in biology, but rather what the word 'isolation' means when it comes to people rather than animals and plants. New Guinea is undeniably big enough to have its own impressive physical barriers to communication in the form of mountains, swamps, and treacherous rivers. However, New Guinea is not much bigger than the state of Texas, and Texas is not even in the running when it comes to language diversity. Whatever has led to the growth of so many languages in the New Guinea region, this diversity cannot be summed up in an equation that includes measures only of island size or island ruggedness.

What then does need to be added to the story? Could it be something specifically human, rather than something geographical? Does New Guinea's linguistic diversity have something to do, say, with warfare, sorcery, political institutions, or religious ideas that have put people so much at odds with one another that they have been out of touch for countless generations?

Archaeologists have established that people first reached and settled New Guinea about 40,000–45,000 years ago, if not before then. This is a lot of time, and from a linguist's point of view, more than enough time for a great many different languages and even language families to evolve—so much time that while New Guinea's own 900 or so languages may sound like an incredibly large number, this count is actually many orders of magnitude *smaller* than the number we ought be hearing on this island, assuming the linguist's rule-of-thumb should be taken seriously that it requires about a thousand years or so for a language to evolve into two mutually incomprehensible 'daughter' languages. Given 40,000 years, it should now be possible to hear something on the order of $2^{40}$ languages (that is, 1,099,511,627,776 languages) on this island. Hence the real conundrum is not just why there are so *many* New Guinea languages, but also why there are so *few* (Foley 1986).

The idea is widely accepted that counting languages is important because *language = people*. As the human geneticist Luca Cavalli-Sforza and his colleagues, for example, wrote: 'except in the case of large modern nations in which the identity of original tribes is usually—though not entirely—lost, languages offer a powerful ethnic guidebook, which is essentially complete, unlike strictly ethnographic information' (Cavalli-Sforza et al. 1994: 23).

Said another way, language differences are generally seen as an easy way to define, locate, circumscribe, label, and index human societies (or 'populations') for data retrieval and comparative research without having to show or establish that the 'ethnic groups' or 'ethnolinguistic populations' thus

recognized linguistically are real societies in any meaningful sense, genetic or otherwise.

In the late 1980s my colleague Robert Welsch and I decided to explore whether linguistic boundaries on the Sepik coast of northern New Guinea are also social boundaries. We saw this coast as a strikingly appropriate place to do research on this purported relationship because partitioning people by language on this coast is perhaps more extreme—and has evidently been more sustained—than anywhere else on Earth. By some counts, over sixty languages belonging to perhaps twenty-four different language groupings are spoken along the 710 km of beaches and small offshore islands between Jayapura in Indonesia and Madang in Papua New Guinea. Furthermore, these many language groupings have been assigned by linguists to five unrelated language phyla: Austronesian and at least four non-Austronesian phyla.

This linguistic situation is not just surprising, it is also astonishing. People on this coast are simply not isolated from one another by mountains, rivers, or deeply ingrained traditional hostilities. On the contrary, they are linked with one another by inherited inter-generational friendships and economic relationships into a vast community of culture, common goals, and shared interests (Welsch and Terrell 1998).

With regard to the three elementary questions I raised earlier, it is standard and usual in archaeology to see non-random similarities in material culture as potentially able to tell us about human social relations expressed as (a) inter-generational learning and the *inheritance* of skills, goods, and possessions; and (b) intercommunity learning and the *acquisition* of skills, goods, and possessions (Shennan 2008). In keeping with this conventional idea, Welsch, John Nadolski, then a graduate student at Northwestern, and I examined over 6,000 items safeguarded in the collections at the Field Museum that had been purchased by museum curators and others before the First World War at thirty-one coastal and offshore island communities on the Sepik coast of Papua New Guinea located between Humboldt Bay in Papua, Indonesia, and Malala (Kronprinzhafen) in Papua New Guinea (Fig. 2.1). We recorded our observations and counts in a village-by-object-type cultural database.

What we discovered surprised us (Welsch, Terrell and Nadolski 1992). Yes, there was a positive correlation—although not a very strong one—between variation in material culture among these thirty-one communities before the First World War and language differences; similarly, there was a negative correlation—although again not a striking one—with geographic distance. However, we also found that language diversity and geographic distance along this coastline are correlated with one another, i.e. they co-vary. While it could be that both of these two dimensions of life—language and geography—need to be equally taken into account when trying to explain variation in local material culture, we ultimately decided that variation among the village collections at the Museum should be attributed chiefly to isolation-by-distance, not language differences.

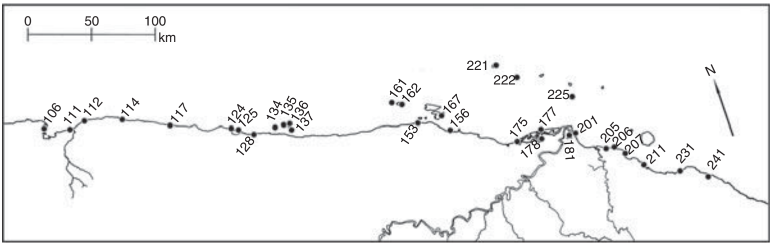


**Fig. 2.1.** Sepik coast of Papua New Guinea—numbered locations are the villages included in the material culture database analysed (revised and redrawn from Welsch et al. 1992: Fig. 1).

Soon after publication of our findings in the *American Anthropologist* in 1992 we were taken sharply and repeatedly to task by several commentators for both misrepresenting and statistically misinterpreting our own empirical data. Analyses of our published dataset by others since 1992 have usually concluded, contrary to our own findings, that 'language and distance account for almost identical amounts of variation among material culture assemblages, jointly accounting for 81 per cent of observed variation' (Moore and Romney 1994: 387).

Perhaps, but logicians warn that it is a logical fallacy to assume that correlation proves causation. As we observed in 1992: 'This analysis suggests that when language variation correlates with variation in material culture, the association is chiefly a consequence of the geographic clustering of related languages on the coast' (Welsch et al. 1992: 585).

Recently, after years of letting the matter lie fallow, I decided to see if modern SNA approaches could resolve the 1990s stalemate about language and material culture on the Sepik coast. Fig. 2.1 shows the location of the communities on the coast we had included in our original 1992 analysis. Fig. 2.2 is an SNA mapping of the expected effect of geographic distance on social relations among these thirty-one communities when the threshold distance is 90 km or less, the minimum distance linking all of the vertices (i.e. these communities) into a single relational network.

The important thing to observe in this second figure is how remarkably restricted in their geographic reach are all of these language families with the notable exception of the Austronesian-speaking communities—just as we had noted in 1992. Fig. 2.3 is a first-, second-, and third-order proximal point analysis (one of the graphical network techniques I had devised in the 1970s; see Terrell 1986: 130–1) of these same communities carried out to identify probable geographic 'neighbourhoods' along this coastline.

In the SNA mappings shown in Figs. 2.4–2.6, the vertices or nodes are all of one type. They represent these communities on the Sepik coast and nearby offshore islands where the Field Museum's collections were obtained. The edges show how

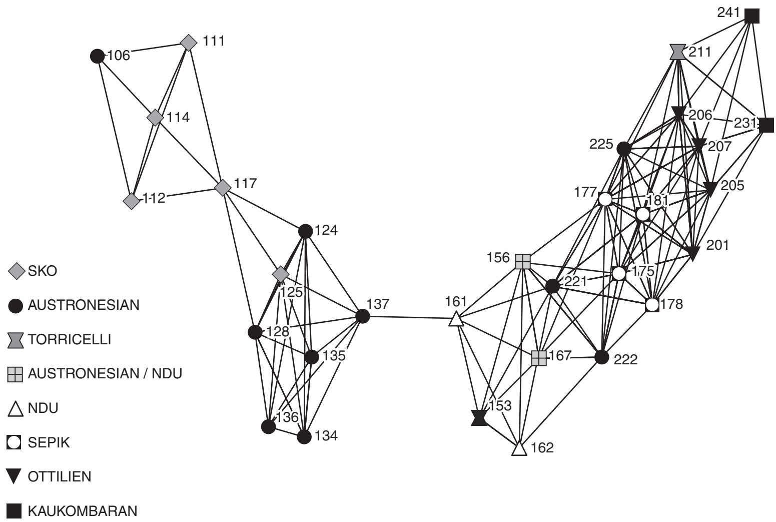


**Fig. 2.2.** Expected effect of geographic distance on contact among places on the Sepik coast. Spring-embedding network array (see Terrell 2010a for details) of the thirty-one communities represented in the dataset when the threshold distance is 90 km or less, the minimum distance linking all of the nodes (places) into a single resulting network. Note how restricted are all of the language families represented in the database with the exception of the Austronesian-speaking communities. *Key*: the language families represented in the dataset.

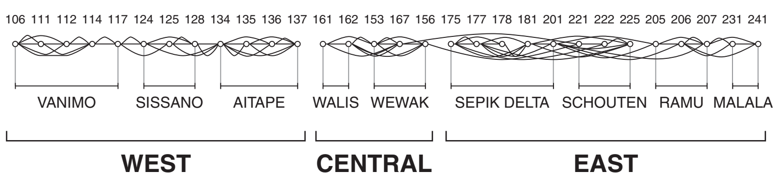


**Fig. 2.3.** First-, second-, and third-order proximal point mapping of expected geographic neighbourhoods (localities) along the Sepik coast in the area represented by the dataset (node 211 has been excluded).

strongly these communities resembled one another before the First World War in their material culture possessions based on their computed similarity to one another in our original 1992 village-by-object-type cultural database.

Fig. 2.4 reveals that variation in material culture on the coast subdivides, as anticipated by this proximal point analysis, not by language affiliation but instead into three geographic localities, or 'neighbourhoods': west (106–137), central (153–167), and east (175–231). Note also, as expected, that communities in the central locality are linked more frequently with places in the eastern area than with those in the west. Furthermore, the observable

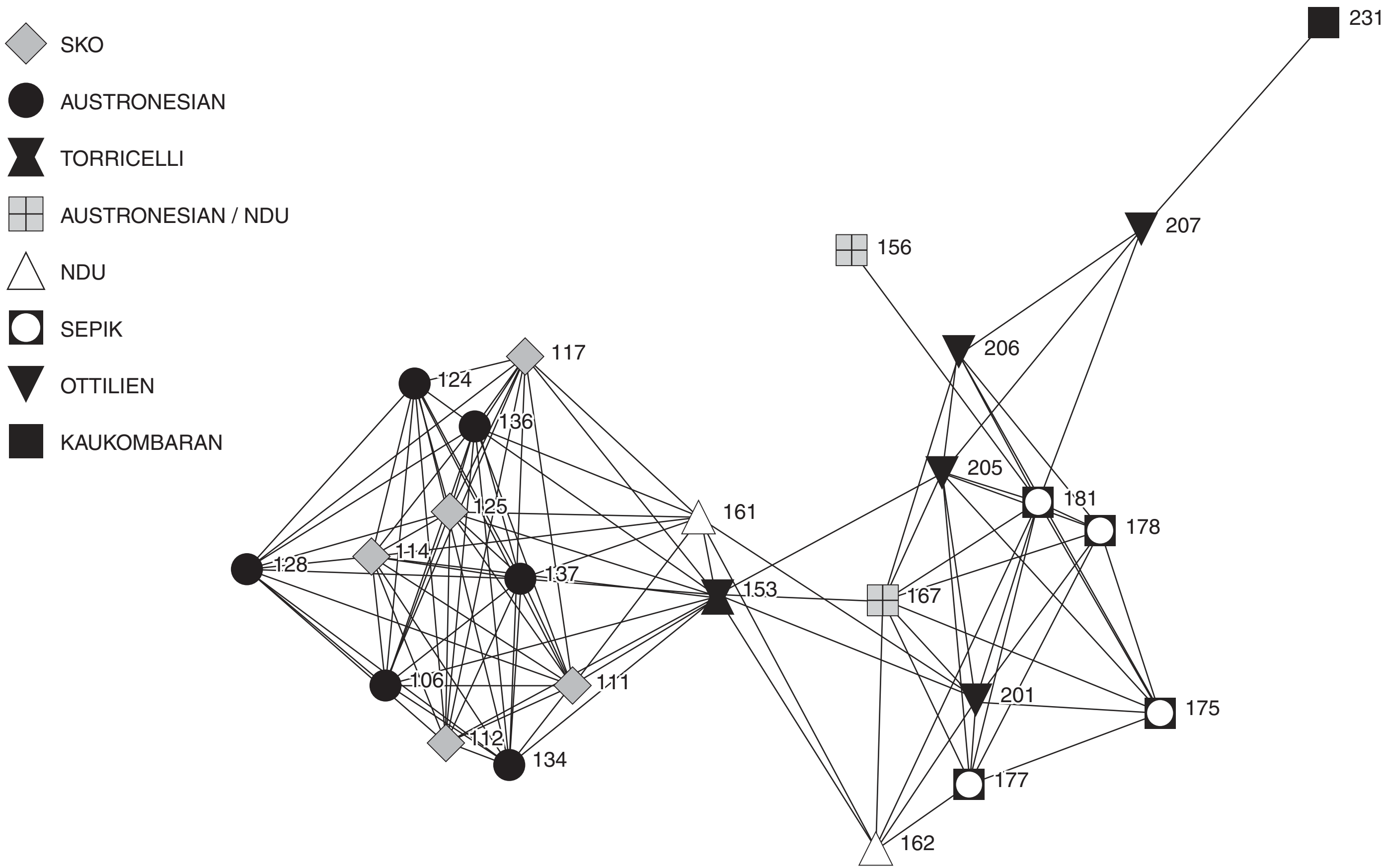


**Fig. 2.4.** Network mapping of the correlation values among the twenty-five of the thirty-one communities represented in the dataset when the threshold is a value greater than or equal to 0.39, the minimum value needed to link all of the nodes (places) in the array (nodes 135, 211, 241, 221, 222, and 225 have been excluded; see Terrell 2010a for details).

commingling of communities, regardless of their language affiliation, is stronger among western communities than among those in the east. Additionally, as shown in Figs. 2.5 and 2.6, this pattern remains in force even when the threshold similarity level is raised to $\geq 0.70$, and then to $\geq 0.90$.

If irony has to do with the lack of fit between what is expected and what is seen, then the results of these SNA analyses of our 1992 dataset are ironic only if you expect to see the equation *language* = *culture* in operation on the Sepik coast. Yet it is now even more obvious thanks to these modern SNA methods than it was in 1992 that language is associated with material cultural similarity among these coastal communities because—as we had observed back then—language diversity in this part of New Guinea is patterned by the geographic clustering of the language communities included in our study.

Therefore, whether language has much to do with the material cultural variation among these communities is moot. Since this is not what common sense leads us to expect, I see this as a useful example showing the value of adopting SNA methods in anthropology and archaeology. The Sepik coast of New Guinea has a lesson to teach us. As the old saying goes and these SNA mappings show us, appearances can be deceiving. Despite the remarkable language diversity found along this coastline, everyone there shares basically the same pool of cultural ways and means patterned at most only weakly by geography, and little if at all by language.

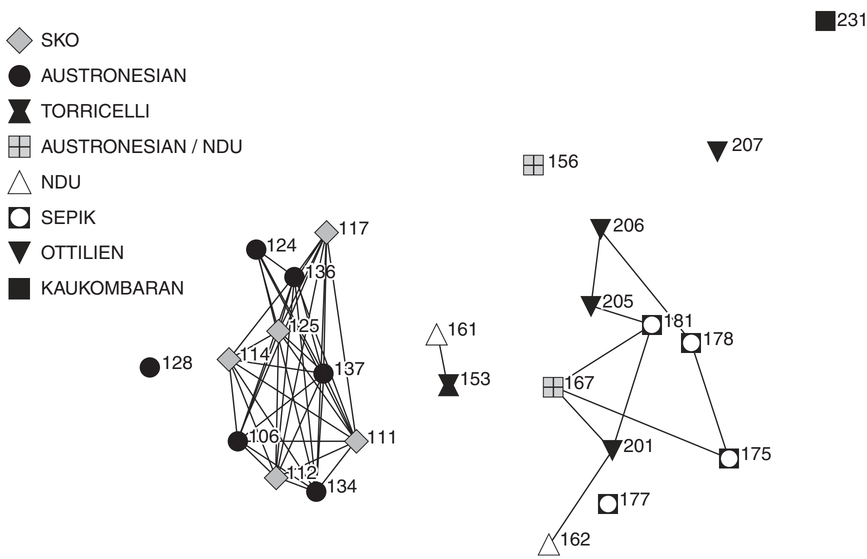


**Fig. 2.5.** Network mapping of the correlation values among the twenty-five of the thirty-one communities represented in the dataset when the threshold is a value greater than or equal to 0.70 (nodes 135, 211, 241, 221, 222, and 225 have been excluded; see Terrell 2010a for details).

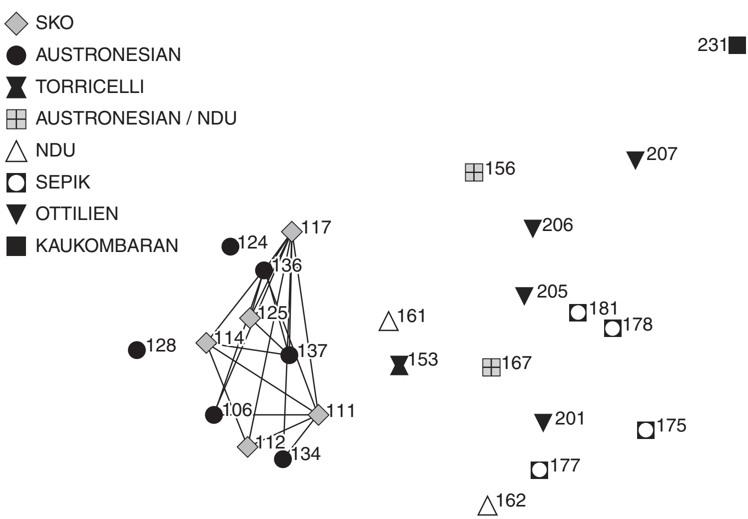


**Fig. 2.6.** Network mapping of the correlation values among the twenty-five of the thirty-one communities represented in the dataset when the threshold is a value greater than or equal to 0.90 (nodes 135, 211, 241, 221, 222, and 225 have been excluded).

### 2.2.2 Linguistic and Biological Variation

Ideally the word *population* when used in the social and biological sciences refers to a socially bounded genetic breeding unit (Mayr 1976: 320–323). In practice, however, it is difficult to show that people residing in a given hamlet, village, town, city, or jungle outpost actually belong to a genetically circumscribed (i.e. isolated) social group that has persisted for more than a generation or two. Change the word *population* here to *society* in the sense of not just 'social' but 'societies', and the same observations apply. Unquestionably *population* and *society* are useful conceptual tools; however, they both can be utterly misleading words when it is assumed without careful assessment that 'populations' and 'societies' actually exist in the real world of blood, flesh, and tears.

In 2007 and 2008 three associated biological studies (Friedlaender et al. 2007, 2008; Hunley et al. 2008) done by the same research team were published on autosomal genetic variation and mitochondrial DNA diversity among people on Bougainville Island in the northern Solomon Islands and on several of the islands located to the north-west of there in the neighbouring Bismarck Archipelago (Fig. 2.7). The authors of these three studies reported that genetic variation among these islanders is organized, or structured, geographically by variables they labeled *island*, *island size/topography*, and settlement *location* (i.e. coastal versus inland). In two of these studies perhaps

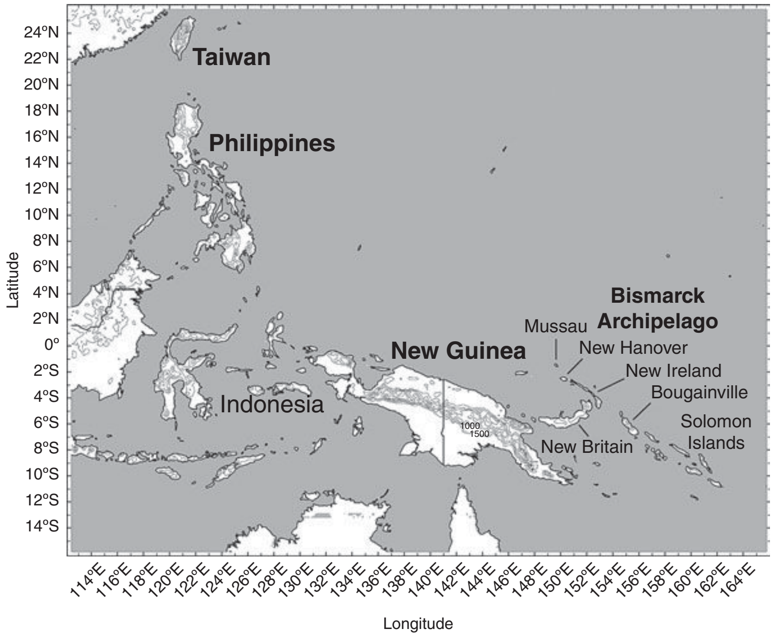


**Fig. 2.7.** Map of the south-west Pacific showing places discussed.

more strongly than in the third, the authors also concluded that at least some of the genetic differences seen among these many 'island populations' are pre-existing ones marking the migratory trail that the prehistoric ancestors of the Polynesians purportedly took to get all the way from Asia to the archipelagoes of Fiji, Tonga, and Samoa around 3,000 years ago. These authors are open about acknowledging that they see their molecular genetic findings as contradicting the view that Fagan and I had first advanced at the AAPA meetings in 1975, although they do not specifically refer to that paper, but rather to ones published later (Terrell 1988; Terrell et al. 2001; Welsch et al. 1992).

In the 1990s when molecular geneticists started looking intently at biological samples taken from Pacific Islanders, the idea gained purchase that there are two opposing models accounting for the origins of today's Polynesians—and by extension, all so-called Austronesians. The first of these grand explanations got labelled then—evidently without irony being implied or intended—as the 'express train to Polynesia' model (Diamond 1988). Basically this is the conviction of long standing, somewhat refurbished, that the forebears of the Polynesians came into being somewhere in Asia (specifically on Taiwan), and then travelled directly from this place of origin, this homeland, to Polynesia in the Pacific Basin. The supposedly alternative hypothesis was dubbed at first by geneticists as the 'Melanesian model' (Redd

et al. 1995), but it is nowadays more widely known as the 'entangled bank' model (Hurles et al. 2003). It is hard to say what this latter model allegedly maintains, and it has been given various and contradictory interpretations (Terrell 2000, 2001a).

In sum, the express-train model elevates the concept of a 'population' not only to new heights, but also across great distances. For example, according to one of the three reports under discussion, the research team responsible for them was able to identify 'a small but clear genetic coancestry between certain Taiwanese populations and Oceanic-speaking groups in Island Melanesia, as well as a much stronger Taiwan Aboriginal signal in Polynesia, indicating that intermixture over the past 3,000 years has not completely erased genetic signals of early Oceanic origins' (Hunley et al. 2008: 13). Or as phrased in another one of these reports: 'Our analysis indicates the ancestors of Polynesians moved through Melanesia relatively rapidly and only intermixed to a very modest degree with the indigenous populations there' (Friedlaender et al. 2008: 1).

Fig. 2.8 is an SNA mapping of the genetic diversity detailed in these three reports. This mapping shows how clearly our genetic diversity in this part of the Pacific is patterned by geography. Fig. 2.9 is a mapping of the expected linkages among the communities in the northern Solomons and the Bismarck Archipelago when the threshold for the geographic ties (edges) is set at a geographic distance of 118 km or less—the minimum geodesic distance permitting all of the nodes (communities) represented to be joined into a single network. The coding of the nodes reflects genetic similarity when the similarity threshold for cluster membership is set at >0.80 (clustering breaks down when the threshold is higher than this). Note that there are six discernible clusters at this level of similarity.

Since this mapping and others of the same genetics dataset have been published in full elsewhere (Terrell 2011b), let me note here only that these mappings show that human genetic diversity in the south-western Pacific is patterned to some extent by isolation-by-distance constrained by social networks (Fig. 2.9) rather than by *island* or *island size/topography*—contrary to what the authors of these reports have inferred. Said colloquially, genetic differences in this part of the world are evidently not determined by islandness, big or small, rugged or genial, but instead by 'hi, do you come here often?'

Additionally, while it is said in these reports that a migration of people from—or at least from the general vicinity of—Taiwan was chiefly responsible for the settlement of Polynesia, the 'genetic signature' these researchers use to support this claim, as shown in Fig. 2.10 (open circles), is geographically widespread throughout this part of the Pacific from the northern Solomons to Mussau Island, and from there to west New Britain. Furthermore, the communities having this purported 'signature' are otherwise genetically quite

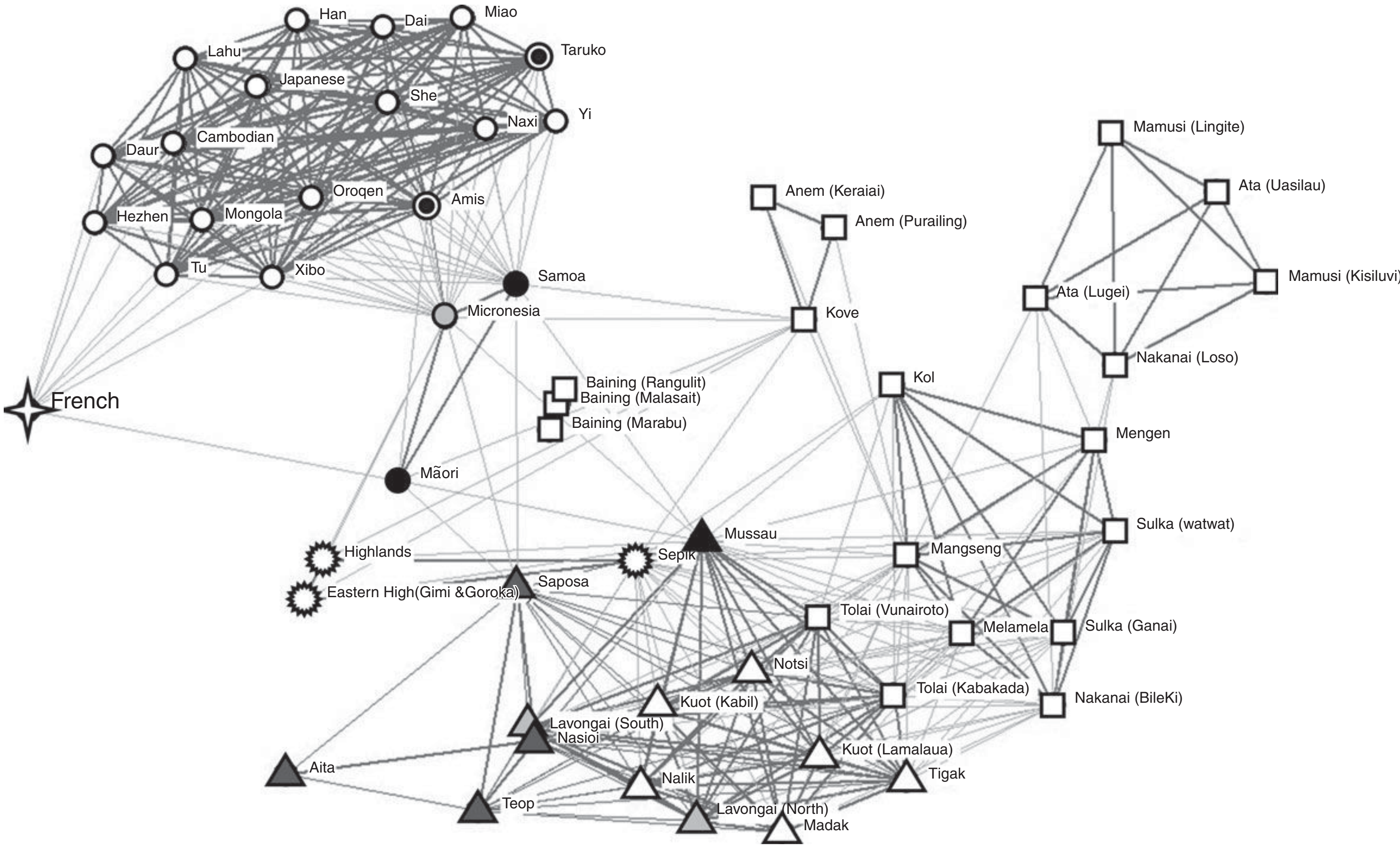


**Fig. 2.8.** Network mapping of the localities included in the genome scan (see Terrell 2010b for details). Mapping derived from the mean STRUCTURE assignment probabilities when K = 10 reported by Friedlaender et al. (2008), colour-coded by geographic location. *Open circles* = Asia; *target circles* = Taiwan; *open cross* = Europe; *black circles* = Polynesia; *grey-filled circles* = Micronesia; *open squares* = New Britain; *gear-toothed circles* = New Guinea; *dark grey triangles* = North Solomons; *open triangles* = New Ireland; *light grey triangles* = New Hanover; *black triangle* = Mussau.

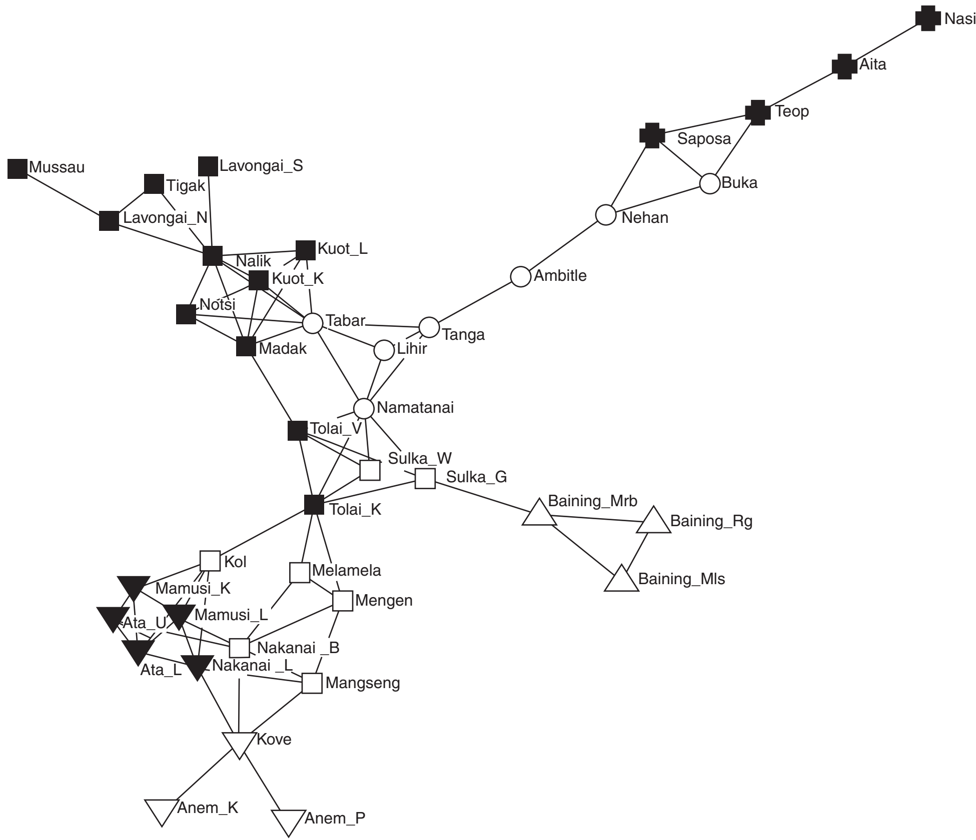


**Fig. 2.9.** Nearest-neighbour structuring of interaction among the localities represented in the genetic study when the threshold geographic distance is 118km or less (the minimum distance linking all of these localities into a single network) and the 'resistance', or 'friction' of inland travel is adjusted by a factor of 7.375 (p = < 0.136), coded by genome cluster (open-circle nodes represent locations not represented in the study; see Terrell 2010b for details).

similar to their neighbours who lack it. This purported Taiwanese signature is also no more prominent on Taiwan than it is today in the south-western Pacific. Given its geographic distribution and the observed frequencies of expression here and there, it seems probable that this signature evolved somewhere in the Bismarck Archipelago and was then later carried at various times and in various ways during the Holocene both westward to some parts of island south-east Asia and eastward into Polynesia—an inference now known to be fully in keeping with more recent molecular genetic research on mitochondrial DNA diversity in this part of the Pacific (Soares et al. 2011).

## 2.3 DISCUSSION

Archaeologists today who are anxious to embrace Darwinism as their paradigm of historical process make the reasonable claim that 'cultural traditions and innovations are socially transmitted person-to-person between and within generations' (Steele et al. 2010: 3781). Where they go wrong—and I think they err in this regard—is to insist that if you want to study history defined in this fashion, you have to assume not just that people are social learners, but also that history manifests itself as 'a historical signal within the cultural traditions carried by populations' (Steele et al. 2010: 3781). In other words, for self-described 'Darwinian archaeologists', history is not just history, but 'population history'—the story of different populations, societies, or cultures.

My father liked to ask people 'if you say *cogito ergo sum* before *non sum qualis eram bonae sub regno Cynarae* are you not putting Descartes before the Horace?' If you are an archaeologist, saying you are trying to reconstruct prehistoric societies, populations, or cultures can be a handy way of talking about what you are doing. But I think my two SNA case studies summarized here show that it is possible to study socially transmitted 'cultural traditions and innovations' without having to suppose beforehand anything whatsoever about the 'deme-based [i.e., population-based] structuring of transmission pathways', or that human populations 'eventually diverge, generating branching trees of historical relatedness' (Steele et al. 2010: 3782, 3783). Making these assumptions a priori is not only unnecessary, but also a fine case of putting the cart before the horse.

I think the same mistake—putting Descartes before the Horace—is commonly done by archaeologists who see human history as an accounting of the evolution of 'complex societies'. For instance, according to Joyce Marcus at the University of Michigan, archaeologists must know the 'level of complexity or sociopolitical integration' of people in the past before they can compare and contrast how people made their way through life (Marcus 2008: 252). In her opinion, 'some kind of social typology is necessary to facilitate comparisons

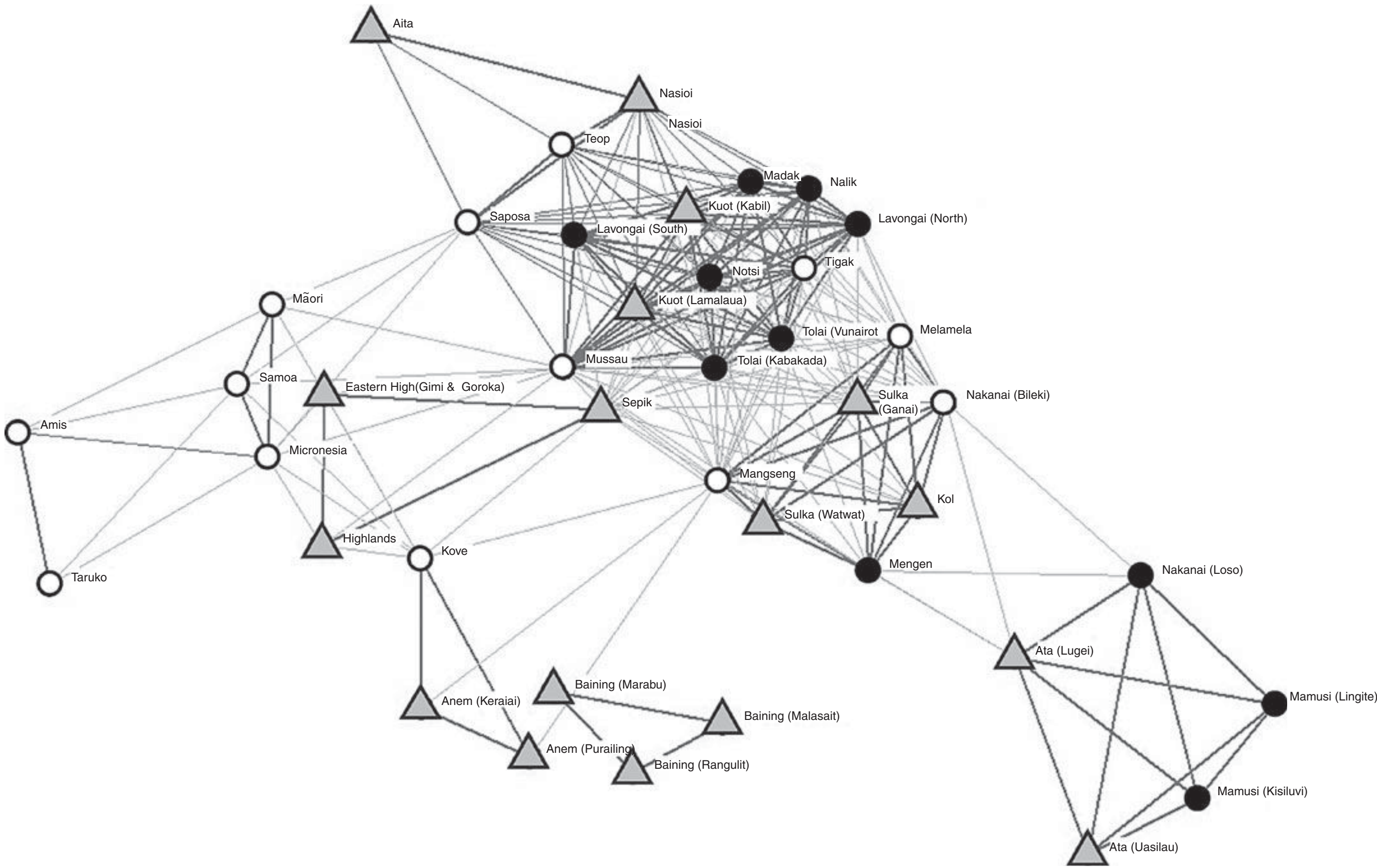


**Fig. 2.10.** Network mapping of only the Pacific Island populations in the genome scan (Taiwan included) derived from mean STRUCTURE assignment probabilities when K=10 reported by Friedlaender and his colleagues (2008), coded by language affiliation (*black circles* = Austronesian; *grey triangles* = Papuan; *open circles* = Austronesian [AN] languages whose speakers have an Austronesian signature >0.04).

and contrasts'. Again, I think a lot of comparing and contrasting can be done using SNA methods without having to make any a priori assumptions about anyone's 'level of complexity'.

Like Marcus, my colleague Bill Parkinson at the Field Museum is also interested in the evolution of complex societies. He has become well-known as someone who wants archaeologists to reinstate the term *tribe* to facilitate making the kinds of cross-cultural comparisons that Marcus (2008) favours. He is evidently convinced that such terminology 'is a necessary evil within the social sciences, where the unit of analysis is seldom clearly defined' (Parkinson 2002: 2). Unfortunately, as he freely admits, this evil entails asking archaeologists to commit to the task of identifying where social boundaries were drawn by people in the past—a job that he acknowledges is far from simple:

> A pressing problem in the discipline of anthropological archaeology is the meaning of the circles we draw on maps to define archaeological 'cultures.' . . . Most archaeologists believe that these materially defined 'cultural boundaries,' which frequently are based upon the distribution of a few specific elements of material culture—usually ceramic or lithic types—correspond to some sort of social boundaries in the past. But few would argue—or at least admit publicly—that the distribution of those boundaries correlates directly to the distribution of actual 'emically defined' social units on the prehistoric landscape. While we have learned that 'pots do not directly equal people,' we remain unsure what the distribution of similar elements of material culture across a landscape does equal. (Parkinson 2006: 33)

Judging by what these and other archaeologists today are saying about their practice of history, I think at least two lessons can be drawn from the two SNA analyses I have commented on briefly here. First, by using SNA methods, it is possible for archaeologists to compare and draw inferences from the distributions of elements of material culture (and other kinds of archaeological evidence) without having to put people into a priori typological boxes of any sort, Darwinian or social evolutionary. Second, SNA methods can also be used to demonstrate why archaeologists find it so difficult to pin down social boundaries in the past. Put simply, people do not actually live in boxes, typological, social, or cultural. Instead, they live in social fields that rarely, if ever, have borders and boundaries that can be properly discovered by drawing circles around things plotted on maps (Welsch and Terrell 1998). In the jargon of modern SNA, human social relations can be mapped far more effectively as edges and vertices. And let's admit it. History is full of wonderful examples showing that 'who's in' and 'who's out' of the networks people construct for themselves and others can change just about as quickly as friending or unfriending someone to your personal *Facebook* account.

## 2.4 CONCLUSIONS

The first chapter of *What is History?* talks about the give-and-take between the historian and what for want of a better way of saying it most of us would simply call 'historical facts'. E. H. Carr is forthright in saying that for him, the practice of history is 'a continuous process of interaction between the historian and his facts, an unending dialogue between the present and the past' (Carr 1961: 35). The second chapter makes it clear that in this regard, he sees the historian as just a particular case of a general condition called being human:

> Society and the individual are inseparable; they are necessary and complementary to each other, not opposites.... As soon as we are born, the world gets to work on us and transforms us from merely biological into social units. Every human being at every stage of history or pre-history is born into a society and from his earliest years is moulded by that society. (1961: 36, see also 1961: 42, 69)

On first reading, these words may give the impression that Carr would have agreed with both Marcus and Parkinson on the need to write about *societies* as well as *society*, but I doubt it. True, in this quotation and elsewhere in *What is History?* he talks about societies as well as society, but he does so in the sense of a bumper sticker that might read 'write locally, think globally'.

> The facts of history are indeed facts about individuals, but not about actions of individuals performed in isolation, and not about the motives, real or imaginary, from which individuals suppose themselves to have acted. They are facts about the relations of individuals to one another in society and about the social forces which produce from the actions of individuals results often at variance with, and sometimes opposite to, the results which they themselves intended. (1961: 64)

There is no disputing taste. Yet if this is the kind of history that appeals to you as an archaeologist, then I suggest you consider including SNA methods in your tool box.

## ACKNOWLEDGEMENTS

I thank Mark Golitko, Ph.D., and Nicola Sharratt, Ph.D., for their helpful comments on the evolving manuscript of this chapter, and also Professor Carl Knappett, Ph.D., for organizing the symposium at the Society for American Archaeology's 75th Anniversary meeting in St. Louis, Missouri, in April 2010—a gathering of like-minds that gave birth to this chapter and this volume.

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# 3

## ‘O What A Tangled Web We Weave’—Towards a Practice That Does Not Deceive

*Leif Isaksen*

### 3.1 INTRODUCTION

Archaeological network analysis has experienced something of a minor boom of late and this cannot entirely be put down to the ‘social network revolution’ post-2000. A number of archaeological network volumes were published only around the emergence of these technologies (e.g. McCormick 2002; Knappett 2005: 64–84) and, indeed, digital prosopography has not featured strongly in the genre as a whole (but see LGPN 2010). More likely it seems to have been a response to a growing interest in network science spurred on by the growth of the World Wide Web (Barabási 2002). Network visualization and analysis tools form an attractive counterpoint to Geographical Information Systems and archaeologists, ever the magpies of the academic world, have been quick to explore their potential.

Yet the phrase ‘network analysis’ is deceptive for it conceals a very wide range of techniques designed for different purposes. The fundamental simplicity of the network concept, composed of just nodes and connections, makes it remarkably versatile but equally dangerous. It can be hard to see past their striking visual representations and apparently objective metrics to the complex set of factors that give rise to them. This complexity comes with its own set of demands—few archaeologists have the mathematical training to fully understand complex network equations and even those that do are likely to grasp only a limited subset of all the possibilities network science affords. Thus, peer review and critique continue to rely heavily on good faith, survey articles (e.g. Brughmans 2010), and critical volumes such as this. Nonetheless, for network analysis to provide any value to the wider discipline it must be possible for mainstream archaeologists to avoid at least the major bear traps. While acknowledging its potential for complexity we must not allow it to

become an academic voodoo. There is strong need, then, to identify key areas of relevance for archaeologists, or to put it another way: what questions should non-mathematicians be asking when approaching network diagrams and metrics?

This article attempts to contribute to that effort by reflecting on three projects with which the author has been, and continues to be, involved. It is therefore an attempt at self-critique with all the caveats such a task implies. It also has heavy leanings towards textual networks, a result of the author's research interests. The relationship between text and the 'real world' is ever-present but it may therefore speak less to prehistorians than those working in the archaeology of literate cultures. It is offered, however, in the spirit demanded of the situation we find ourselves in: as nodes within our own academic network, who at best can hope to act as the 'long ties' that shorten its informational distance.

The following section is a high-level overview of some fundamental issues encountered by archaeological network analysts. It acknowledges that these are frequently tensions between conflicting demands and that there may be no 'correct' balance. The subsequent sections describe the demands of the three projects and the network approaches used to address them. This is followed in each case by a discussion of the strengths and limitations of the method adopted and, where known, suggestions as to how it might be improved.

## 3.2 ISSUES

So what kinds of network analysis are used by archaeologists? Three broad themes seem to stand out—visualization, metrics, and experimentation—although in practice these are often combined. Each is essentially a means of simplifying the complexity of the real world, although this not always evident when working with them!

**Visualization** is ostensibly the most straightforward, the practice of generating a network to be looked at whether digitally or in print. While this may seem like an 'unscientific' approach, it is in some ways the most powerful, bringing the full human cognitive system to bear on a dataset. The human brain is strongly configured to identify patterns, real and imagined, and this often helps to bring out insights and intuitions that would not have occurred when looking at lists of figures. Unfortunately the brain is also easily fooled to recognize false patterns where they do not exist, a phenomenon known as apophenia or patternicity (Shermer 2008). Many network analysts see visualization as a vital part of their research for producing hypotheses that must then be supported with greater reliability through statistics.

**Network metrics** can be calculated and this paper will look at just a handful of them (called centrality indices). They provide important, and often surprising, evidence which can be compared with the hypotheses typically generated by visualization. They are also amenable to visualization themselves (usually as charts) which in turn can trigger new ideas. Their quantitative and apparently objective nature can seem more persuasive than viewing a network directly, but placing additional weight upon them is rarely justified in the archaeological sphere, as we shall see.

**Experimentation** may take two forms—data testing and variable testing. In the first case, we aim to discover whether data exhibit a certain expected characteristic: that members of a certain class of node are significantly more interconnected than other nodes in the graph, for example. Variable testing is more abstract—the archaeological data may not always be sufficient to generate even an approximate network. In such cases hypothetical networks can be created and by adjusting variables it is possible to see how they affect its network structure. These can help provide insight into the impact of such variables in the real world.

One final aspect to consider is the relationship between networks and **geography**. Networks themselves are topological and need not have a spatial dimension. They are multidimensional, however, which makes spatial representations a natural way to think about them. This in turn has made them attractive to those working with geographical data (and especially GIS) as a way of exploring spatial relationships that do not conform to Euclidean or spherical geometry. There is, however, nothing uniquely 'geographic' about networks and attempts to represent them spatially come with their own set of challenges.

If these are the kinds of use to which we put networks, what are the issues we must consider when doing so? Let us start by asking what a network is. The answer for a network scientist is relatively simple: it is a set of nodes and the links that connect them (Barabási 2002). A range of additional variables can be incorporated, such as directionality, weighting, and so on, but without specifying a domain—the real world phenomena to which they refer—such graphs can only answer abstract questions. It is precisely at the intersection of graph theory and the discipline to which it is applied that things get messy. Humanists are (generally) well aware that imposing categories upon the materials and relationships under consideration may be an extremely useful heuristic tool but it is no more than that (e.g. Baines and Brophy 2006). All such divisions tend to break down under close enough scrutiny and an infinite number of alternative classifications can be produced. This has two consequences for domain-specific network analysts. The first is that meaningful network analysis cannot be applied *without* categorization: the minimal definition for an edge ('has a relationship to') would lead merely to a trivial graph in which all points were connected. This in turn requires us to perform a kind of semantic

bootstrapping: we must choose a set of categories ahead of time that we deem to be meaningful. This process is not entirely self-referential. If archaeology is ultimately the study of what it means to be human (through the legacy of our material culture) then humans arguably have a privileged insight unavailable to computers. Nevertheless, all judgements of archaeological network analyses must begin by asking why a given concept set—places, typologies, people, and so forth—was used for it entirely determines the nature (if not the structure) of the results.

With the semantics of the network forming the fundamental basis for critique, a number of follow-up issues should also be considered:

*Automated versus manually generated*: This has major epistemic ramifications for the results. If the semantics of networks are heavily dependent on human involvement then we must be extremely careful when evaluating networks that have been created automatically. In a manually created network there is an inherent presupposition of agency behind each element—this is not the case for automated networks. What is the algorithm that generated it? What is the source data? Automated networks should be extremely explicit about what they are intended to portray. On the other hand, manually generated networks are almost always much smaller, and therefore potentially much less robust. Of course it may be possible to aggregate networks generated by multiple individuals but this can introduce issues of semantic dissonance which may be both pervasive and hard to detect.

*Representation*: Those used to working with data are well aware that there is no 'correct' way to visualize them—different methods highlight some aspects at the expense of obscuring others. This is particularly the case when converting linear scales (like numbers) to visual analogues such as colours or shapes: false colour gives the impression of banding to the human visual system, log scales may not be apparent when shown as a line width, and so on. Ideally, the data and visualization tools themselves should be made available to the research community (including the general public) so that they too can get a 'feel' for its internal structure. In practice this is not always possible but publications should endeavour to highlight such symbolizing decisions and how they were taken.

*Epistemology*: Network analysis must be seen as a single tool in the archaeologist's toolbox for understanding the past, not an end in itself. Despite their visual appeal and concrete-looking numbers, their relationship to the real world is always tenuous and restricted. Even such abstract conclusions may have real value, however, when combined with other archaeological information. Correlating networks with independently derived data is another important means of validating it, but it is not explanation in itself.

*Change*: Most archaeological networks of interest are likely to have a temporal component. The tendency to ignore this aspect in metrics and visualizations cannot only suggest much greater connectivity than exists at

any given point in time but also hide important structural phenomena and render networks meaningless. Where possible the temporal nature of relationships should always be taken into account.

*Completeness*: We have seen that all networks are ultimately a selection of what appears to be relevant to the analyst. Nevertheless, archaeology is a notoriously incomplete domain: absence of evidence is not evidence of absence. This has particular significance for network analysis where large-scale network effects can be caused by very small changes in the data (think of the removal of 'bottlenecks' like bridges in a transport network). It is important to consider the robustness of a network when considering its epistemic value. How much random corruption could occur to the dataset before the analysis gave an entirely different result? This can be very difficult for an external viewer to gauge and is more properly the job of the analyst to report.

*Networks of reality and perception*: As we have seen, it is impossible to entirely divorce the 'real' from our perceptions of it, but there are times when we are reporting on secondhand data, particularly when working with texts. In such cases we must be especially clear that network analysis is fundamentally a way of trying to understand a world-view, rather than the world itself.

This is not an exhaustive list, merely a useful set of criteria by which archaeologists can begin to judge the work of network analysts. In the spirit of such endeavour we now turn to three projects that the author has undertaken in order to take stock of the methodologies used.

## 3.3 VISUALIZATION: PTOLEMY

Claudius Ptolemy's *Geographike Hyphegesis* ('Guide to Drawing a World Map' but better known as the '*Geography*') is unquestionably one of the most important texts in the history of its subject matter. Written in Alexandria in the mid-2nd century, its reappearance in western Europe in 1397 revolutionized Renaissance geography and helped pave the way for the Age of Discovery.[1] Yet despite its historical significance it remains a deeply problematic text. The most challenging issue is the sheer scale of the catalogue, comprising some 8,000 or so locations that stretch from the Atlantic Ocean to China and from the Baltic Sea to Tanzania. Not only are we left bewildered as to how Ptolemy managed to amass such an enormous quantity of data when no other similar document has survived, but its very size also renders it virtually intractable for analysis on a place-by-place basis. Some have argued that it must be inauthentic on the basis that some place names demonstrably

[1] For an introduction to the work and its later significance, see Berggren and Jones 2000.

post-date Ptolemy's lifetime (Bagrow 1945), but how representative are those places? The work is composed of both theoretical chapters and a catalogue of locations but its innovative format of coordinate tables—explicitly intended to encourage insertion and correction—hides the stylistic hints we might turn to in more traditional material. An important recent development is the publication of a new German translation of the complete text with a database of Ptolemy's coordinates by the University of Bern (Stückelberger and Graßhof 2006). This makes it possible to visualize the data in a variety of ways, including both geospatially and as a network in order to surface structural phenomena that may hint at the origin of Ptolemy's sources.

For instance, statistical analysis of the coordinates demonstrates that their precision varies (Marx 2011). However, those locations that must have been assigned at the highest level of precision (one-twelfth of a degree of arc of latitude or longitude) are only found within a constrained region of the map adjacent to the Mediterranean (see Fig. 3.1).[2] Unfortunately, the independent nature of each location makes it difficult to establish whether these 'high precision' coordinates are related in any other way than their proximity.

At a macro level, the ordering of coordinates in the Geography is non-random. Locations are divided by region ordered from Northwest (Ireland) to South East (Sri Lanka). Within each region a strict ordering takes place: (1) Boundaries (including coastal and border settlements) are listed first, followed by (2) physical geography (especially mountains chains). Once these structural elements have been given (3) inland settlements are named before finally (4) offshore features (generally small islands) are identified.

Categories (1) and (2) generally form linear features, reflected in their ordering; Ptolemy starts at one end and works his way along coastlines, for example. The beginning and end of mountain chains are also sequential, as are islands along the littoral in (4), so far as is possible. These seem such natural orderings to us it is easy to forget that this is an intentional strategy and partially masks the nature of his source material. So what of category (3), inland settlements? These have no natural ordering (other than Ptolemy's arbitrary NW–SE trend) so what might their sequence reveal about Ptolemy's *modus operandi*?

We can test this very easily by simply 'joining the dots' in the order they are listed. Each point was classified based on the categories above. Lines were then auto-generated between them. One complexity arises from the fact that

[2] The locations here are from the more accurate, but truncated, Chi-recension supplemented by the complete, but more corrupt Omega-recension. 'High precision' coordinates that fall on Ptolemy's parallels representing 'length of longest day' have also been omitted. All coordinates are from Stückelberger and Grasshof 2006.

**Fig. 3.1.** The distribution of high precision coordinates in the *Geography* is highly centralized.

Ptolemy usually provides his locations in tables of varying length (sometimes with just a single location) based on sub-regions within each category. Joining the last location in one table with the first location in the next occasionally creates connections between widely separate locations. In contrast, not joining them leaves frequent gaps and sometimes, in cases where locations are given individually, results in no line at all. Both results are informative although the latter graph provides a clearer overview especially after removing the geophysical and offshore features (Fig. 3.2).

Once again we see a strong disparity between the core regions and the periphery. In the core regions, coordinates appear to group together in tightly bunched clusters. At the periphery they are generally 'sketched out' in linear rows, usually horizontally (northern Europe, much of Asia) or vertically (northern Libya), but occasionally in a SW–NE sweep (India). Laying 'high precision' coordinates over these features shows more clearly the correlation between this stylistic variation and the 'core' data we identified previously (Fig. 3.3).

Other phenomena also start to stand out, such as the high correlation of regional boundaries in Europe with the traditional Greek parallels and 'hour intervals' (increments of 15 degrees of longitude) described by Ptolemy (see Fig. 3.4). The parallels are based on length of longest day—the historical means of determining latitude—although the text suggests that actual measurements were taken in only a handful of locations (Ptolemy, *Geog.* 1.4). The problem of calculating longitude (Sobel 1995) would have made hour intervals significantly harder to establish and geographic assignment to these zones seems to have been a matter of educated guesswork rather than geodetic measurement.

What might we conclude from this? First, and in conjunction with the 'high precision' points, we can see that there are clear structural differences within the data. This has enormous consequences for future study of the *Geography* for it means that it cannot be analysed either as though it were a homogenous whole or by piecemeal study of individual locations. Problematic locations, such as those identified by Bagrow, must be considered in the context of related points, and network visualization helps to indicate the appropriate geographic regions of analysis. Second, and no less importantly, the evenness and regularity with which the locations are recorded in many regions suggest that Ptolemy's data do not stem principally from his assumed source, Marinos of Tyre, who provided limited spatial coordinates, but most likely so-called *chorographic* (illustrated regional) maps. If this is the case, then Ptolemy's coordinates can only be extremely rough approximations of location, despite the remarkable level of accuracy at a global level.

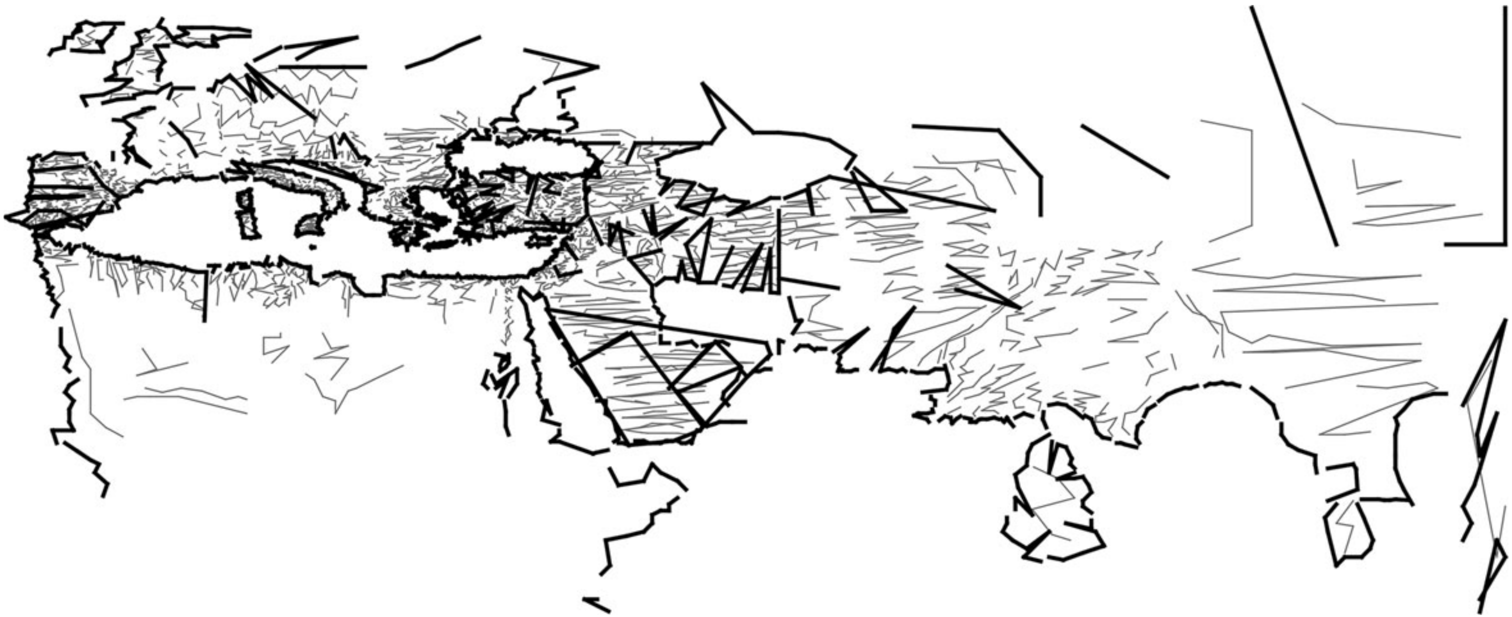

**Fig. 3.2.** Lines interpolated between inland settlements in the *Geography*.

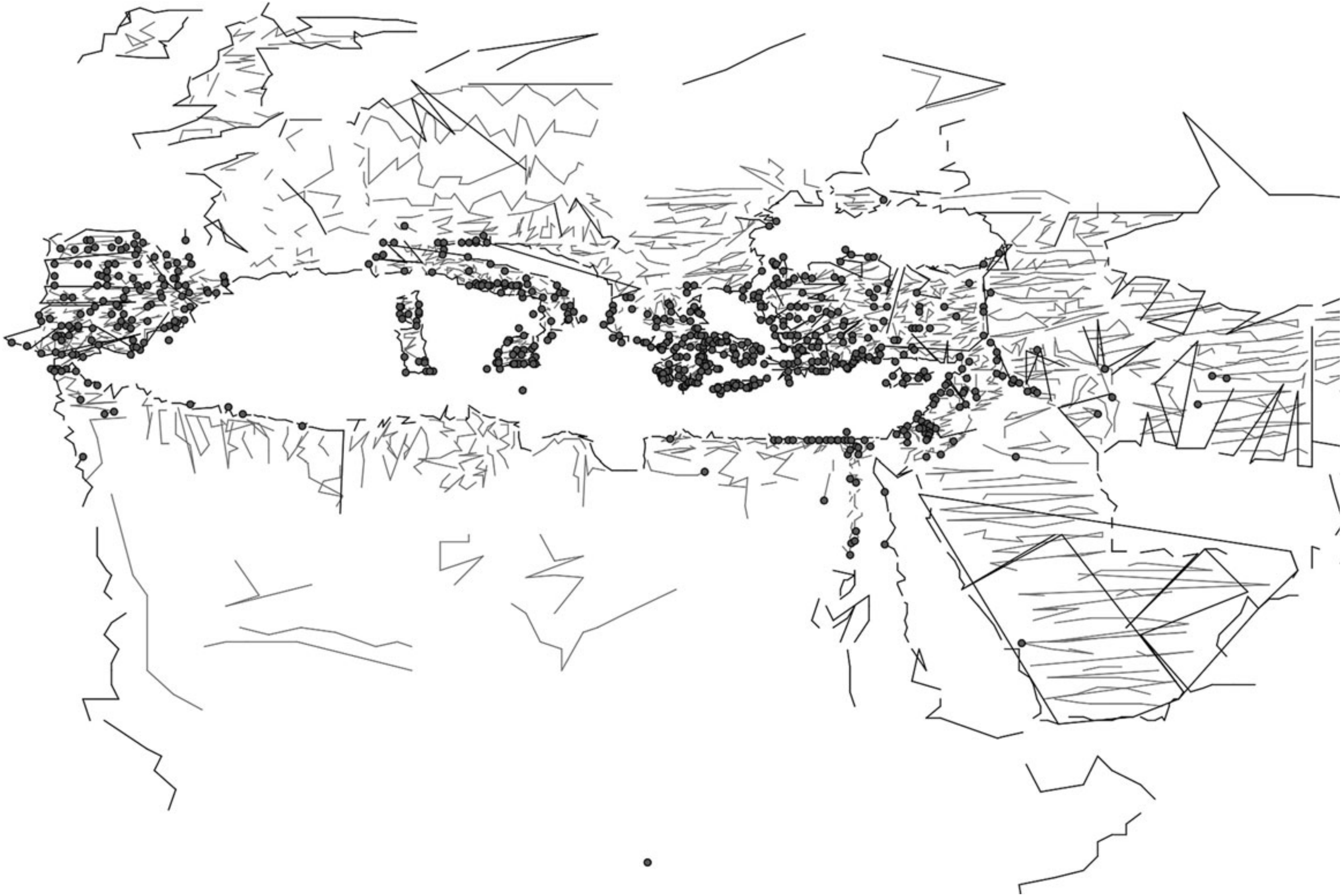

**Fig. 3.3.** 'High precision' coordinates show a strong correlation with the clustered patterns of settlements typical of Ptolemy's core data.

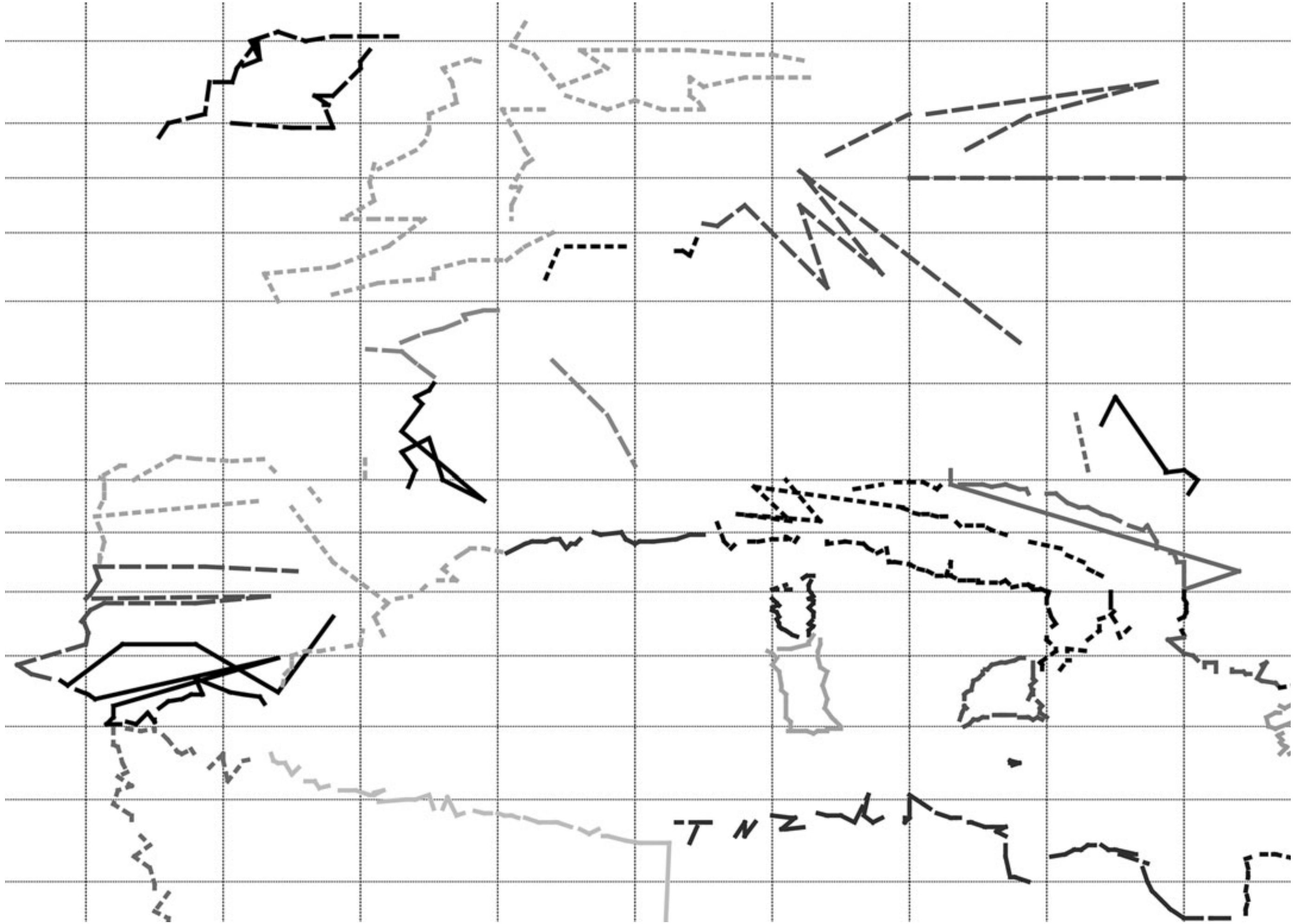

**Fig. 3.4.** The boundaries of Ptolemy's regions, as defined by the coastline and river sources, often correlate strongly with the traditional series of Greek parallels.

## 3.4 CRITIQUE

It seems clear that network visualization can play an extremely useful role in tackling large, complex datasets with a geospatial component but this is also an unusual case—typically we take the data for granted and are trying to see what it tells us about the world. In this case it is the nature of the data itself we are trying to understand through network analysis.

Another unique feature of the dataset itself is that it is strictly linear; i.e. there is a sequence in which locations appear in the text. The catalogue occasionally refers to the same location multiple times so there is limited potential for identifying 'hubs' within it, although it is not entirely clear what the significance of these would be. They are generally points where several borders intersect but typically appear to be of minor importance otherwise. Again, in contrast to conventional network visualization it is the *spatiality*, not the *topology* of the network which is of interest here, despite the fact that it is not real geographic space, but space as conceived of in Ptolemy's chorographic sources.

One aspect that has not yet been properly explored is the directionality of the network. This is to some degree a limitation of the software used (the PostGIS spatial database and QGIS viewing software) and the approach taken of treating every line independently and using colour coding to indicate association. One feasible technique may be to use increasing opacity over the course of a line series to give an effect similar to using dried up marker pens on a white board. This would permit direction to be made clear while maintaining colour as means of signifying category.

The research is still a work-in-progress but concrete results are now beginning to emerge, based on statistical approaches, close reading and extensive background research. Network visualization has played a key role in stimulating new ideas about the sources of Ptolemy's data and the structure of the coordinate catalogue but [is not] sufficient in itself to explain them.

## 3.5 HETEROGENEOUS DATA: THE PORT NETWORKS PROJECT

The second case study is the author's doctoral research, focusing on the integration of archaeological excavation data from Roman harbour sites around the Mediterranean. It is part of [t]he Roman Ports in the Western Mediterranean Project[3] directed by Prof. Simon Keay.[4] Its principal methodology is to

3 <http://www.bsr.ac.uk/BSR/sub_arch/BSR_Arch_05Roman.htm>
4 University of Southampton/British School at Rome.

establish the co-presence of ceramics and marble at a range of key sites as a means of gauging fluctuating trans-Mediterranean interaction during the Roman period. Source data comprise large quantities of published and unpublished harbour and shipwreck excavation databases from a variety of academic and research institutions in different countries.

While the datasets all pertain to the same domain, they frequently employ mixed taxonomies and are heterogeneously structured. Normalization is rare, uncertainty frequent, and variant spellings common. Different recording methodologies have also given rise to alternative quantification and dating strategies. The project is international, with resources in English, French, Spanish, Italian, and Catalan. In other words, it is a typical real-world, mixed-context situation. As an international endeavour, requiring the synthesis of large quantities of data with varying format but restricted scope, it is an ideal opportunity to work through data integration issues, and in the case of the author's research, Linked Data approaches to them.

Linked Data uses a graph structure spread over the World Wide Web as a means of describing data (Berners-Lee 2006). Nodes are Uniform Resource Identifiers (URIs), effectively address spaces on the Web, and the links are provided by the Resource Description Framework (RDF), a data format which binds together URI nodes as subject-predicate-object statements. This graph-based approach is vastly easier to integrate automatically than the tabular schemata of relational databases, although the semantic complexity involved can be arduous to negotiate. In essence, any two graphs which share at least one URI can be immediately combined in principle. How the resulting super-graph ought to be interpreted is a much more complex problem. Archaeologists will typically cherry-pick from a variety of different typological series, use varying levels of temporal and spatial granularity and quantify assemblages in fundamentally different ways (by weight, minimum count, or estimated count, for example). Knowing the context in which a classification or measurement was made is not always possible.

There are additional socio-technical problems to consider. Linked Data is a comparatively new approach to data management. Not only are there few tools available to produce it but there are even fewer to consume it. Its principal strength lies in the possibilities for integration with other Web resources, but there are currently few archaeological data out there in a Linked Data format and archaeologists are often reluctant to make their raw data visible to others outside of *quid pro quo* arrangements. The only way to break out of this circle of mutual exclusivity is to make the advantages of sharing as clear as possible, providing new ways for archaeologists to look at their own data while drawing on whatever public resources may exist already. The author's research has attempted to do this partly by means of a series of tutorials which archaeologists can use to produce Linked Data, and partly by

developing software tools that transform the resulting RDF output into digital formats with which they are more comfortable.

An example of this is the integration of Linked Data sets produced by the archaeologists with generic information provided by the public Linked Data encyclopaedia Freebase.[5] Freebase provides an ideal platform within which to store information about general concepts to which archaeologists might refer such as an amphora type or Roman province. By using the Google Refine[6] tool, they are able to map their local terms to URIs provided by Freebase. Although Freebase is publicly editable, it provides its data as RDF, making them easy to combine with archaeological data and enriching them with additional information such as spatial coordinates and images. As a means of helping archaeologists revisualize their own data, a tool was developed that converts this information into the well-known KML format which is suitable for visualizing in Google Earth. It creates a star graph showing the inflow of amphorae from different regions to an excavation site (see Figs. 3.5 and 3.6). Each find is dated to its context, enabling users to trace an approximate evolution of trade over time. Shading was used to highlight specific provinces with line width representing volume. Each node (represented by an icon or pushpin) provides an information balloon with specific details about the assemblage. The goal is to provide an overview of the data that is easy to digest quickly, provides access to more detailed information and can be easily combined with additional data. Much as with Linked Data itself, [KML] enables multiple networks to be combined simultaneously.

## 3.6 CRITIQUE

There seems little doubt that visualizing the information in this way can be extremely useful for gaining a rapid overview of amphora distribution patterns. A more hard-nosed question would be to what degree it is aligned with the needs of those who must process the data. At time of writing, the level of engagement so far suggests that archaeologists are capable of converting the data from traditional spreadsheets and databases to a Linked Data format, but that in practice the effort (approximately a day's work) may be, or seem to be, too great for the perceived return. We should consider that practising archaeologists will already have a very deep understanding of much of their own material, and overviews, no matter how visually appealing, may simply not be a sufficient incentive for the extra labour. On the other hand it may be that

[5] <http://www.freebase.com/>
[6] <http://code.google.com/p/google-refine/>

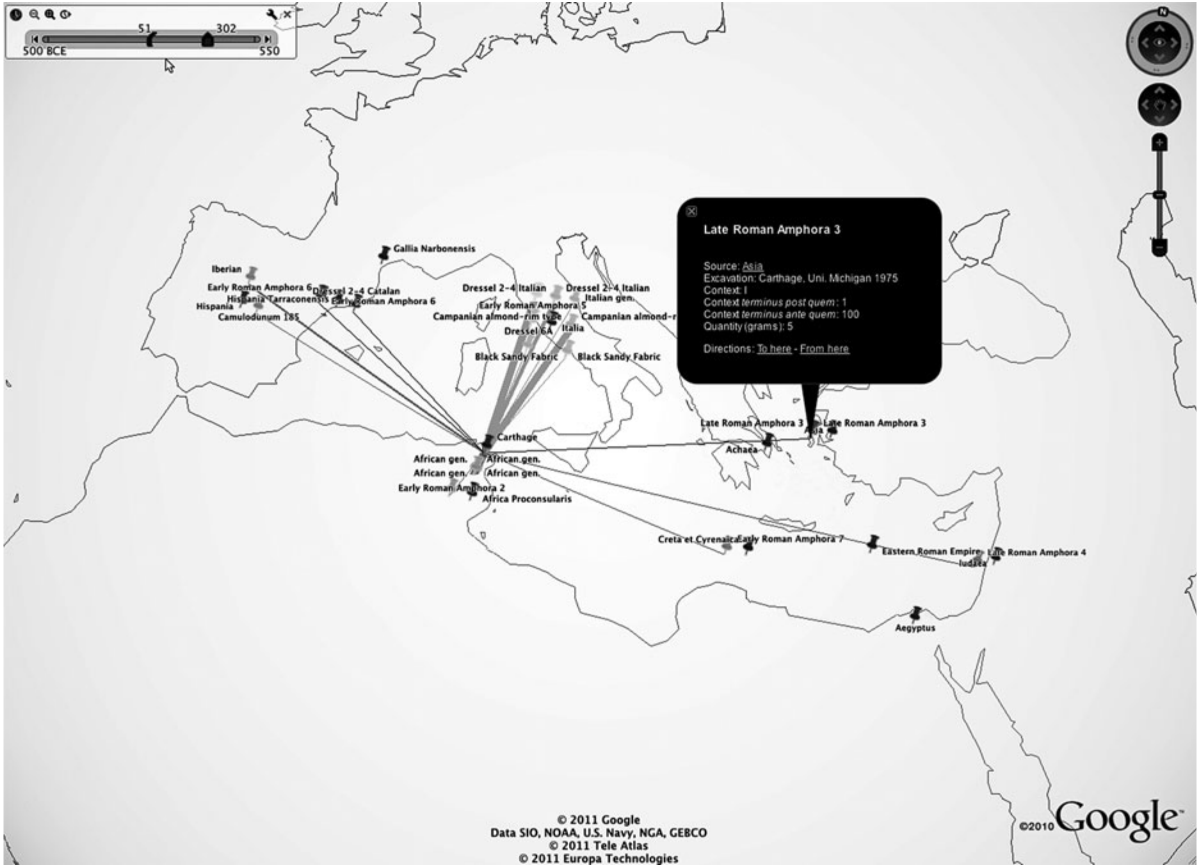


**Fig. 3.5.** A network diagram representing the import of amphorae to Carthage *c.*50–300 CE.

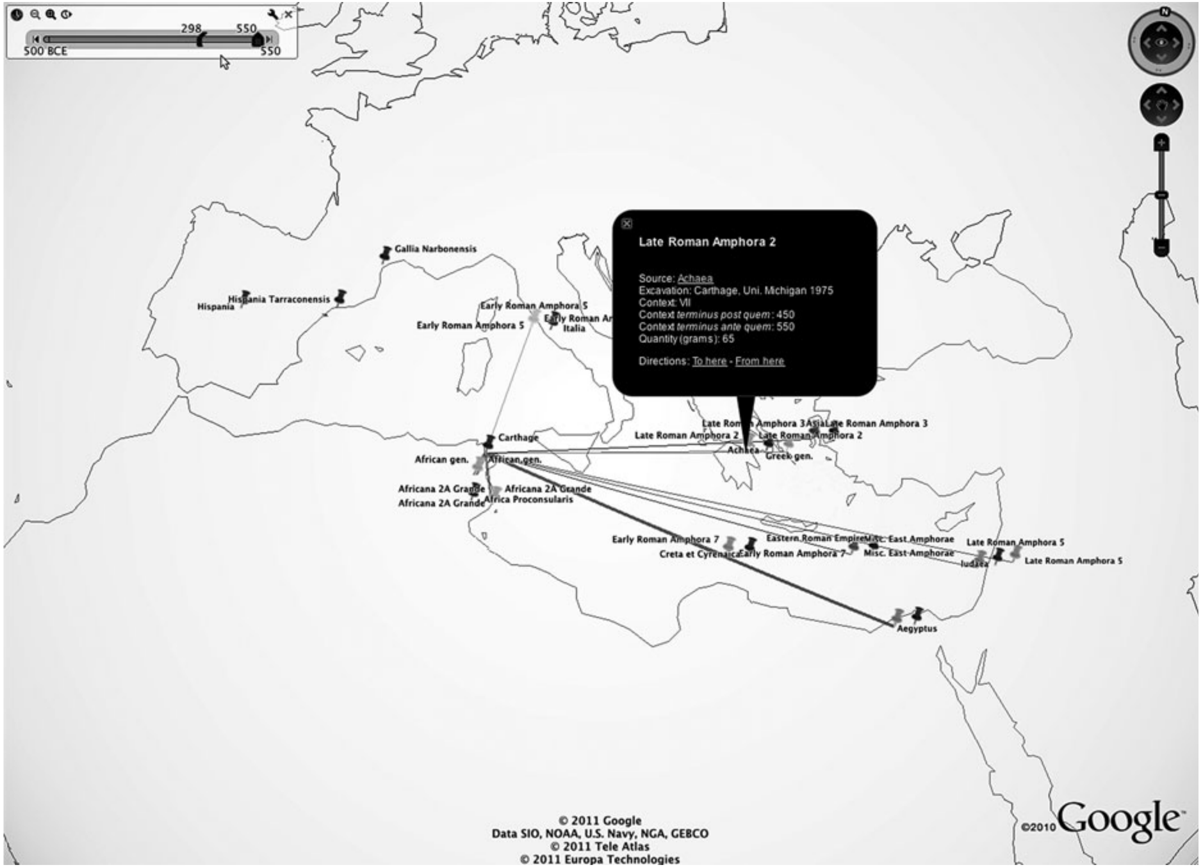


**Fig. 3.6.** A network diagram representing the import of amphorae to Carthage *c.*300–550 CE.

there is simply not yet the 'critical mass' of open content needed to make the case for Linked Data compelling.

A variety of other aspects of the project also deserve reflection. With regard to visualization, there is much that is potentially deceptive here. First, and perhaps most importantly, we need to acknowledge that we are not looking at trade flows but using archaeological deposits as a proxy for them. Almost by definition, any transport between source and destination must predate the time of its deposition. Furthermore, dates are based on the *terminus ante quem* and *terminus post quem* of the contexts. As a result, those finds with only loose dating appear to have been 'traded' for longer. When combined with line weighting, an entirely false picture can potentially be given. Likewise, a large, well-dated deposit might give the impression of a single large shipment, but in fact be the re-use of a dump of amphorae accumulated over a century or more. There is no way to visualize generically such complex movement and deposition processes. More realistically we must try to identify higher-level phenomena, such as clusters of imports from the same region over the same time, which may represent a genuine trade pattern, and then go back to our source data to see if they bear our hypotheses out. To this end, the Linked Data approach is extremely important because it facilitates the aggregation of data in a way that can make such phenomena more apparent. Outliers—deposits which buck the trends—may also be interesting, even providing important caveats to our overall interpretation.

Other deceptive aspects of the visualization include images—which only rarely capture the 'essence' of a typologist's definition—and line-widths as a proxy for volume. Volumes tend to fall on a log scale, with many small deposits and small numbers of very large ones. In some ways this makes volumetric comparisons across sites easier. It is not terribly meaningful to compare minor quantitative differences across sites—far too many other factors come into play. Orders of magnitude are much more helpful as a comparison. There are still important differences to account for however—100 litres of olive oil is probably of less significance than the same quantity of a delicacy like *garum*, and the size of their vessels reflects this. These issues can again be ameliorated by a Linked Data approach to some degree. Recording average vessel size and typical content types within a generic resource can make automated approximate calculations much easier, if some estimate of vessel count can be given.

What possibilities are there for improvement? There are many, although much depends upon the data available. The current approach has been to simplify as much as possible until a balance between effort invested and pay-off for the archaeologist is reached. Once such a balance is achieved it may be possible to add more information to the workflow with time as the gains become more apparent. More significantly for the wider practice, the software is specifically designed for dealing with a specific Linked Data schema and

written in Java, a compiled programming language. Although the tutorials for creating Linked Data can be easily reconfigured by archaeologists with slightly different needs, the software to convert it to KML would need reprogramming, a task beyond even most digital humanities scholars. Rewriting it in a more accessible scripting language (such as Python) would significantly increase its portability and potential for reuse.

Finally we should not forget the fact that the data itself is now recorded in graph form, making it entirely amenable to network analysis itself. Both locations and ceramic types can be seen as hubs, although care should be taken when comparing provinces and archaeological sites. Likewise many ceramics types are effectively identical. There are relatively well-defined ways of dealing with such issues in Linked Data (such as the SKOS[7] and OWL[8] ontologies) but they cannot be ignored before undertaking serious analysis. Fortunately, precisely such work is being undertaken by at least two projects (Brughmans 2010; Foxhall and Rebay-Salisbury 2009) and their results may greatly illuminate both the study of ancient exchange and the potential of network analysis for Linked Data.

## 3.7 METRICS: URBAN CONNECTIVITY IN ROMAN BAETICA

The third case study looks at geographical texts once more, this time Roman itineraries. These are a fundamentally different way of thinking about space than Ptolemy's 'top-down' approach. While their origins are obscure they effectively seem to have acted as route planners enabling Roman travellers to identify a series of day routes that would take them, in sequence, from one location to another until reaching their destination. The itineraries we are specifically interested in are the Antonine Itineraries, The Ravenna Cosmography and the Vicarello Goblets. As sets of itineraries often refer to the same place several times they create topological networks ideal for certain forms of analysis. Nevertheless, like all ancient texts they should be treated with some caution. They should not be confused with transport infrastructure such as roads or ports—they simply indicate that direct passage between two locations is possible, typically (if not always) within a day's travel judging by the distances involved. Different itineraries date from different periods and we cannot be sure that all routes were traversable simultaneously. In the case of the famous Peutinger Table we can be sure that the data has been compiled

7 <http://www.w3.org/2004/02/skos/>
8 <http://www.w3.org/TR/owl-guide/>

from source material that is *not* contemporaneous (Talbert 2010: 134). We do not know whether the itineraries were compiled before, during, or after a specific journey, or merely as a theoretical exercise. Finally, we are generally uncertain whether they are intended to be directional or bidirectional. It is natural to assume that passage in one direction implies that passage in the other is a possibility, but if the routes represent a specific journey, for example, it may be that the ordering serves a specific function.

The geographic scope of the particular study is the Roman province of Hispania Baetica, the area more or less occupied by what is now the region of Andalucia, Spain. Baetica provides an excellent case study for such an approach having a reasonably well-documented (and stable) history, a rich archaeological record and a mixed topography that encourages specific forms and directions of travel. This also has advantages when attempting to understand the internal logic of the itineraries.

The approach adopted was to investigate two network metrics known as *closeness* and *betweenness centrality*, and assumed bidirectional links (edges).

Closeness centrality is the normalized average distance (in links) to every other node in the network. It is an index of how easily accessible a node is and has a value between 0 (inaccessible) and 1 (directly accessible in 1 step by all). Two graphs which demonstrate this most clearly are a simple star graph, in which the central node has a closeness centrality of 1.0, and a cycle graph in which all the nodes have identical closeness centralities. In a network of vertices and lines, $(V,L)$ the function, $cl(v)$, of the normalized closeness of a vertex, $v$, is formally defined as:

$$d(v) = \frac{n-1}{\sum_{u \in V} d(v,u)} \quad (3.1)$$

[9]

where $d(v,u)$ is the shortest path (or *geodesic*), in terms of nodes traversed, between $v$ and any other node, $u$. These distances are summed, and a normalised index is obtained by dividing one less than the total number of vertices $(n-1)$ with this value. Normalization is important as it enables us to compare this node's closeness with that of nodes on other networks.

Betweenness centrality is the probability that a node will be passed by traffic travelling along the shortest route between two other nodes on the network. This is not an index of how easy it is to reach other nodes, but the likelihood of it being en route when taking the shortest path between other vectors. Nodes with high betweenness centrality need not necessarily have a high closeness centrality but they are classically associated with bottlenecks and focal points of systems. Formally,

[9] Batagelj 2005.

$$b(v) = \frac{1}{(n-1)(n-2)} \sum_{\substack{u,t \in v: g_{u,t}>0 \\ u \neq v, t \neq v, u \neq t}} \frac{g_{u,t}(v)}{g_{u,t}} \tag{3.2}$$ [10]

where: $v$ is a node in a network of vertices and lines $(V,L)$,
$g_{u,t}$ is the number of geodesics from node $u$, to $t$, and
$g_{u,t}(v)$ is the number of geodesics from node $u$, to $t$ that pass through $v$.

Once again, the value is normalized to a value between 0 and 1, this time also to take into account the fact that geodesics from $u$ to $t$, and from $t$ to $u$ will both be included in the equation.

Betweenness centrality is the metric that interests us here most because it indicates which nodes have a higher degree of control over the network (Freeman 1977: 35–36). Although this is unlikely to be in the form of obstructing traffic, such key nodes have the potential to influence the way in which that traffic flows, perhaps in a very concrete fashion, as we shall see. They may also benefit from the increased degree of economic activity that is created by the confluence of separate linear routes (Pitts 1965: 15).

The metrics were calculated using the Pajek software package, which is freely available for non-commercial use. As well as providing a sophisticated suite of statistical tools, it also supports topological network visualization, including techniques for symbolizing nodes based on the indices described above. The data itself was held in an independent database with a custom script that allowed data to be exported and imported from Pajek compliant formats. The strength of such a system is its ability to combine multiple networks easily, adding or removing itineraries and nodes as desired. Fig. 3.7 shows a 'super-network' composed of the three itineraries mentioned above, the river transport network, and a route of a single day's journey between Astigi and Ostippo known from *miliari* and aerial photographs (Sillières 1990: 506–8).

A bar chart of the betweenness and closeness of each node in the network demonstrates clearly the key points of control in the system (Chart 3.1). They are Astigi, Hispalis, and Corduba, three of the four regional capitals of Baetica. In other words, *if* the data is broadly representative of the primary transport routes in Baetica, they are unquestionably the focal points of the Baetican transport system.

The use of a database allows us to visualize the network not only topologically but geographically as well (Fig. 3.8). This has the advantage of putting the itineraries in a more meaningful context. In particular we can see that the key location of the regional capitals referred to earlier is at the lowest bridging

[10] Batagelj 2005.

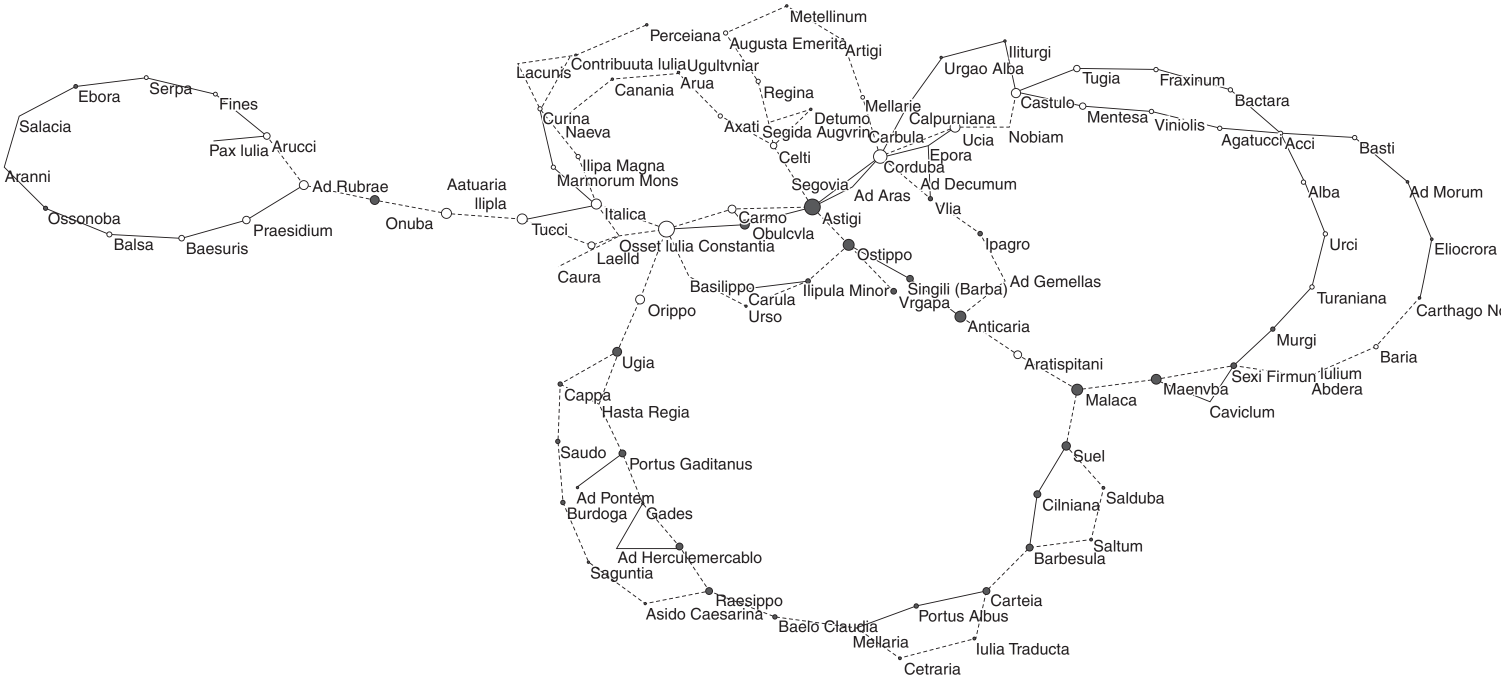


**Fig. 3.7.** Combined network of all known transport routes and itineraries [Node size signifies Betweenness centrality].

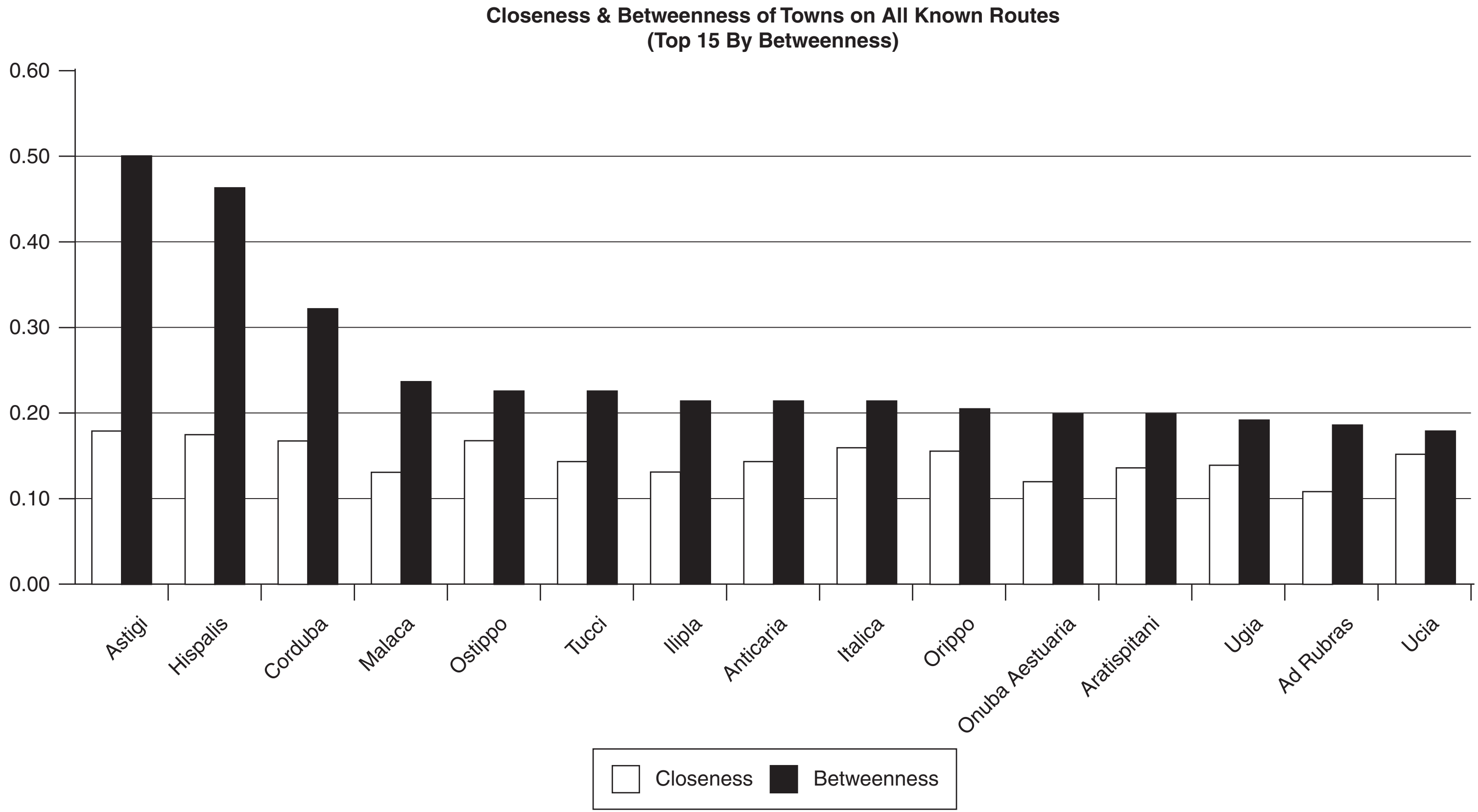


**Chart 3.1.** Closeness and betweenness centrality of towns on all known transport routes and itineraries (top 15 by betweenness centrality).

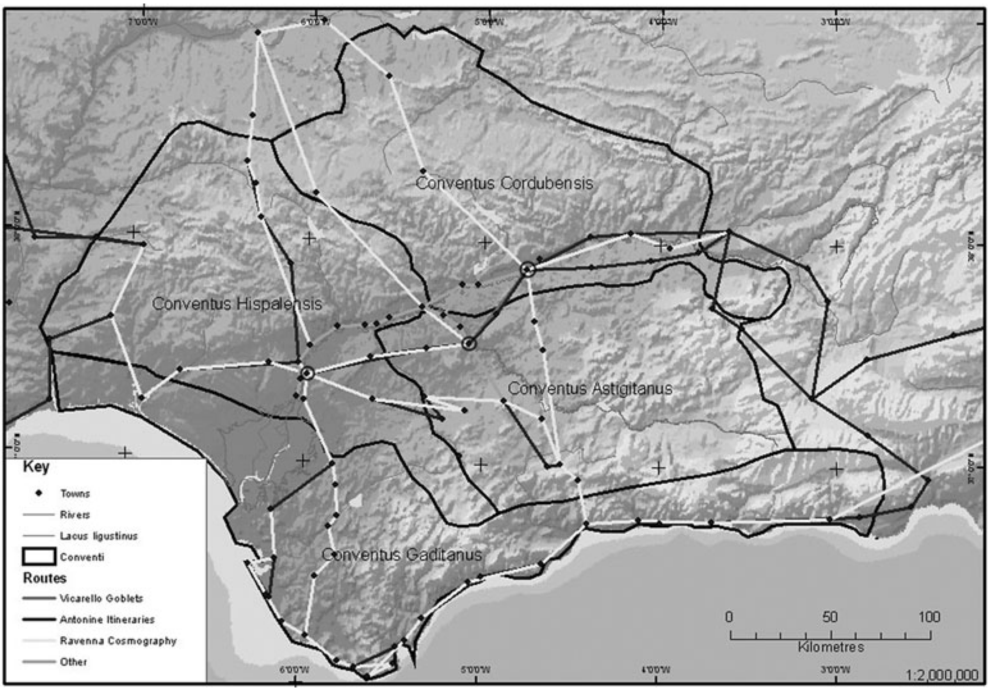


**Fig. 3.8.** Spatial schematic of itineraries from all sources. Corduba, Hispalis, and Astigi are circled.

points on the river (Astigi, Corduba) and the transhipment point between river-going and sea-going vessels at Hispalis.

## 3.8 CRITIQUE

The approach described makes a convincing case that a strong correlation exists between the political status of settlements and their importance within the network. Less certain, perhaps, is its ability to explain that correlation. The original research suggested that the location of sites played a fundamental role in determining their status and while this is no doubt true, it need not have been so apparent within the itineraries. One or two fewer nodes along the Baetis (Guadalqivir) would shorten the network distance of the river route enough to render Celti, located at its confluence with the Singlis (Genil), a more significant site than Astigi. Likewise, the inclusion of the road between Astigi and Ostippo seems, in retrospect, a mistake. We are here attempting to

model a network of perceptions and incorporating elements of material culture is inappropriate in this context no matter how relevant they may seem to the wider interpretation.

This raises a further issue which was not addressed, the robustness of the model itself. The model is largely composed of loops emanating from a well-connected central region but it was not established whether a break in any one, or even several of them, would have a significant impact on the results. An intuitive suspicion is that it would not, given that the key sites are embedded within an inner circuit. The key exception to this is the short mountain pass north of Malaca (modern Malaga). Removing this route would significantly extend travel distances from the littoral to the interior, affecting our metrics heavily. The absence of this stage from the Antonine Itineraries makes Malaca a remote outpost on the Baetican periphery in contrast to its key position in the Ravenna Cosmography, the only itinerary that records it.

One of the more exciting developments since the completion of this work has been the digital publication of the complete itineraries (Talbert 2010). This opens the door to a large-scale analysis of these unique documents and may help to establish whether the patterns that seem to be present in Baetica are local phenomena or representative of the Roman itineraries in general.

## 3.9 CONCLUSION

It is hoped that the foregoing has highlighted both a range of possibilities but also the inherent challenges in using network visualization and analysis for the study of the Ancient World. It is perhaps most noticeable that they are rarely able to prove anything in themselves—more typically they are a gateway to deeper reflection and investigation. They may well bring to light internal structures and correlations but the significance of them is rarely clear at first and more often than not they tell us more about our data than the world itself.

This in turn should lead us to reflect on just how different our own data are from those of the ancients. We frequently assume that scientific method and rational exposition protect us from the pitfalls we detect in the work of others, but perhaps it is precisely here that network analysis has much to offer us. By exposing the limits of our own thought we make it easier for others to critique and thus build upon them. It is hoped that this chapter has identified some of the more significant criteria by which that evaluation can be done.

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# Part II

# Sites and Settlements

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# 4

# Broken Links and Black Boxes: Material Affiliations and Contextual Network Synthesis in the Viking World

*Søren M. Sindbæk*

## 4.1 INTRODUCTION

Long-distance communication has emerged as a particular focus for archaeological exploration using network theory, analysis, and modelling. The promise is apparently obvious: communication in the past doubtlessly had properties of complex, dynamic networks, and archaeological datasets almost certainly preserve patterns of this interaction. Formal network analysis and modelling holds the potential to identify and demonstrate such patterns, where traditional methods often prove inadequate.

Initial attempts to adapt methods from social network analysis to archaeological data have, however, struggled to produce decisive results. This chapter argues that the archaeological study of communication networks in the past calls for radically different analytical methods from those employed by most other forms of social network analysis. The fragmentary archaeological evidence presents researchers with the task of reconstructing the broken links of a ruined network from observable distributions and patterns of association in the archaeological record. In formal terms this is not a problem of network analysis, but network synthesis: the classic problem of cracking codes or reconstructing black-box circuits.

Computational solutions to network synthesis problems have recently been explored in mathematics in terms of probabilistic algorithms for network design optimization. The application of similar formal methods to archaeological datasets holds the potential to generate predictive models. Like any complex modelling, however, they entail a risk of providing black-box solutions to black-box problems—presenting models whose basis is difficult or impossible to assess, and whose predictions may be equally difficult to validate

considering the generous margin of error within which archaeologists need to operate. It is proposed, therefore, that archaeological approaches to network synthesis must also involve a contextual reading of network data: observations arising from individual contexts, morphologies, and use patterns. This point is demonstrated with reference to a study of Viking-period communication in the North Sea region.

## 4.2 ARCHAEOLOGY AND LONG-DISTANCE COMMUNICATION NETWORKS

Network theory and analysis is currently being explored in archaeology as a way of reframing problems of interpretation in new and potentially useful ways. As in other disciplines, network-based methodologies provide archaeologists with potential insight into local and global properties of systems of interconnected objects, which can neither be discovered by studying the interacting agents individually or in pairs, nor by studying the average properties of the system as a whole (Croft et al. 2008: 2). Network models have the power to facilitate structural comparison across different scales and source materials and to formulate hypotheses and models for further exploration (Müller 2009: 752 ff.).

This applies particularly to studies of long-distance communication. In the mainstream of archaeological studies, the latter is often approached in terms of 'contact' or 'exchange'; that is, as infrequent points of intersection, for which discussions focus on establishing the directions and the time when particular contacts 'began' or 'stopped'. This image clearly expresses a simplistic understanding of pre-modern communication. Archaeology, genetics, linguistics, etc., show that some form of communication connected almost every region of the world through all historic and prehistoric periods (LaBianca and Scham 2006). The history of exchange flows, therefore, should not be characterized by identifiable beginnings and ends, but by changes in their mode, course, and intensity. Interactions will have shifted gradually, or occasionally abruptly, between fine-knit meshes of short-range encounters, and directional long-distance journeys.

The fact that vectors of interaction were small-scale and irregular, as was most long-distance exchange before the arrival of bulk-carrying sea-vessels, does not exclude that they had significant impact. Small things carried far could articulate with meshworks of dependencies, tributary obligations, marriage strategies, and other forms of kinship management, which affected the relations between thousands of human actors across wide areas. Material or symbolic assets obtained through long-distance links afforded the accumulation of resources,

or conversely gave the incentives for these to be directed into symbolic and economic links with people beyond the horizon.

Approaching past long-distance communication from a perspective of network theory, we can examine how its organization was characterized in terms of such concepts as closeness, degree, and regularity. Formal network analysis and modelling hold potential for archaeological studies of past communication for two reasons in particular.

First, the flows of communication in and between societies in the past almost certainly had properties of complex, dynamic networks: Communication was carried by the travels of many individuals, who relied on a dynamic stock of cultural knowledge; flows of interaction often followed known and identified routes; they proceeded between a greater or smaller number of fixed destinations—ranging from camps and assembly sites to urban centres—which can be considered the nodes of networks. The use of different routes would have varied historically, subject to political circumstances, cultural perceptions, and dispositions, economic opportunity, and innovations in the technology and skill of travelling. Even the simplest communications system in the past would have implied a high degree of complexity.

Second, modern archaeology offers datasets of great complexity, which may preserve patterns of such networks, and which calls for formal analysis. A feature of culture or technology, which has gained a certain geographical distribution, can be regarded as the object of a successful diffusion, whether through transport from a common source, or through emulation. The focus, extent, and boundaries of its occurrence are likely to reflect critical features of the communications network through which it has been carried (Valente 2005). The regional distribution of archaeological finds and features, in this perspective, is a source of potential evidence of the interactions in communication networks.

As the present volume underlines, the application of network analysis and modelling has begun to make an impact on archaeological studies in recent years. The most definitive results have been obtained so far through modelling based on geographical parameters, as pioneered by Hage and Harary (1991, 1996) and Broodbank (2000), and more recently explored by Knappett et al. (2008, 2011). It is characteristic, however, that all major studies carried out so far concern island networks, in which nodes are defined by natural geography, and space can be modelled as the isotropic surface of the sea (ignoring, for the sake of the argument, the practical concerns of the mariner of winds, currents, coastlines, and reefs, etc.). It remains to be shown how network modelling can cope with the complexities of real physical geography, let alone the dynamic social conditions reflected in archaeological evidence.

Attempts have also been made to use network analysis to quantify statistical properties in archaeological data relating to interaction, in particular to define

measures of centrality and resilience (Johansen et al. 2004; Sindbæk 2007; Mizoguchi 2009; Brughmans 2010). While these and other pilot studies demonstrate that network properties can indeed be distilled from the archaeological record, they also reveal the extent to which problems relating to survival, sampling, and comparability apply even to large and painstakingly researched datasets. For that reason, other archaeologists have found it more reassuring to base explorations into network analysis on the more clearly defined evidence of written sources, such as the Antonine Itineraries (Graham 2006; Isaksen 2008).

Recent studies have sought ways to characterize social and cultural boundaries and community structure by applying network analysis to material evidence (Sindbæk 2010; Terrell 2010). Terrell demonstrates the power of network analysis to facilitate structural comparison by contrasting the affiliations in language and material culture within the same set of thirty-one island communities in Papua New Guinea. My own study, based on archaeological records, integrates the distribution of a group of common artefact types in contemporary excavated sites in the southern Baltic Sea region in the early Middle Ages, in order to characterize the combined patterns of cultural affinity. Both studies reveal patterns which are not obvious in the individual distributions; they independently highlight the significance of proximity along coastal interaction zones as a principal component in the distribution of material culture affiliations (Terrell 2010: 28; Sindbæk 2010: 276 ff.).

Most of the studies discussed above build on techniques associated with so-called affiliation networks (cf. Wasserman and Faust 1994: 291 ff.; Nooy et al. 2005: 101). An affiliation network is a set of actors participating in various groups. This could be a group of people attending various meetings, or the occurrence of certain types of finds or features in sites across regions. Actors are regarded as related if they share a common attribute, i.e. are both members of one or more common groups. Obviously, the discovery of a particular artefact in a site does not prove that people in this place communicated with all other sites where similar finds occur. But the material affiliation implies that the potential for communication between these sites can be regarded as slightly higher than between others, who do not share the same attribute—as two people are more likely to be acquainted if they have often attended the same meetings. The more attributes two actors share, the greater this potential must also be reckoned.

Affiliation networks allow measures of relative centrality and similarity to be calculated and visualized in common network analysis software. However, being concerned with group relations rather than links between specific pairs of nodes, affiliation networks tend to generate dense clusters in which links do not necessarily represent communication, but might rather be imagined as 'clouds' of relatedness. Moreover, most of the statistical techniques by which social network analysts identify attributes and relations, cliques and other

subgroups, or structural roles, are useless or at best imprecise when applied to affiliation networks. Affiliation graphs can be a useful tool for archaeological analysis, making complex arguments transparent without loss of complexity. But as a basis for more refined network analysis, they come with a problem.

## 4.3 THE BLACK BOX PROBLEM

The basic trouble faced in adapting social network analysis to archaeological problems lies in the nature of the available evidence. In social network studies, or indeed most branches of network analysis, the analyst seeks to characterize the structural patterns of a known set of interactions, and to interpret their social implications. The challenge faced by archaeology is often the diametrical opposite. Archaeological data typically represent fragmentary samples of material affiliations, ranging from shared features or artefact types or raw materials to biomolecular markers or trace elements in materials. Most analytical techniques designed for network analysis are not applicable to this form of data. The actual links are broken: at best we may know the location of the input—whence a particular item was derived—and of the output—where eventually it came to be deposited and later retrieved as an archaeological find. We are mostly ignorant as to what happened in between.

In some other contexts of network research, where similar limitations apply, the problems would be negotiable. In the classic 'Travelling Salesman Problem' (of finding the shortest route connecting a series of points), any solution must eventually be a 'network' consisting of a single, continuous line. Although a famously difficult computational problem, exact methods of solution are known. In a similar way, biologists could, even in the days before exact DNA sequencing was practicable, use a simple, relative measure of similarity between animals—for instance, the relative strength of their immunity response to particular strains of disease—and derive from that a precise network of evolutionary relationship between the species in question.

The reason for the success in both cases is that researchers know in advance what *shape* the networks in question will be. Knowing that a travelling salesman must visit every site in his district once, and finish his route as quickly as possible, we know that the ideal route will be a line with no branches or crosses. Knowing that two species, which have once split beyond interbreeding, can never converge, we know that an evolutionary network is a tree, a sequence of stems splitting into new branches. We can assume that observed differences represent splits, and that a relative measure of similarity represents the relative order of those splits. The rest is simple calculation.

Not so in archaeology. In the context of human long-distance interaction we have little way of knowing what shape a particular network will have taken.

Did many sites and individuals interact freely, or did they refer to a hierarchy of mediators and central locations? Did interaction form a busy, interconnected 'global village' with 'loops' of cross-cutting links, or was a relatively sparse set of steady contacts maintained between selected sites? These are not given factors which could be fed into a research design, but questions which we would hope analyses might clarify.

The basic problem is that material affiliations in the archaeological record do not offer a measured network to analyse, nor a foolproof guide to interpret the meaning of any measurable similarity or centrality. Approaches to network analysis in archaeology have overlooked a fine but important distinction: In the terms of a mathematician, archaeologists are not faced with a case of network analysis, but rather of network synthesis—a problem that starts from a known response and seeks a network that will produce that response.

Network synthesis is the problem faced by travelling salesmen trying to sort out their train bookings, or by evolutionary biologists pruning phylogenetic trees. A more pertinent example in the context of archaeological study is the 'black-box' problem of electronics: knowing only inputs and outputs, are we able to reconstruct the components and composition of a hidden electric circuit? Network synthesis has rarely been a concern in social network studies, and this may be at least part of the reason why archaeologists find it difficult to apply inspirations from this field in practice. However, it has a long tradition of research and modelling in studies of logistic or technological networks (cf. research history in Minoux 1989).

Cracking 'black boxes' is computationally more challenging than linking known actors and measuring centrality, clustering, etc. Even simple tasks like identifying hierarchies (as in star or tree networks) or paths (as in the travelling salesman problem) can be computationally difficult problems for which no fast, exact solution is known. This is a field, however, which has received strong interest in recent years, reframed as the very profitable problem of network design optimization (Cheng et al. 2006; Dress et al. 2007).

Being a subject of essential practical interest to computer network designers, spatial planners, or shipping companies and other businesses involving logistics management, network design optimization has encouraged intense work in mathematics and computer science. Notable results have been obtained by applying evolutionary algorithms such as simulated annealing or ant colony optimization. These techniques have been applied with promising results to project optimal traffic flows in highway systems, rail networks, airline service networks, etc. (Randall and Tonkes 2001; Korte 2006; Gen et al. 2008). The results demonstrate that the computational problems of network synthesis can sometimes be fruitfully negotiated. Even if available methods do not provide exact solutions, they do provide stable and workable solutions—sufficiently so to be useful in informing critical economic decisions, such as planning container terminal networks or airline fleet assignments.

Archaeologists, of course, do not aim to design optimal networks for past communication, nor should they expect any real network to correspond to a perfect, optimal state (Knappett et al. 2008, 1014). Any solutions which will have mattered were optimal insofar as they benefited the local and momentary situation of engaged, motivated, decision-making people, rather than as viewed by the global but detached modern analyst. The potential archaeological interest of network design optimization models lies at a more generic level.

Both the data considered and the outcomes aimed at in network design optimization bear sufficient *structural* analogy with the problems faced by archaeologists trying to reconstruct a network of 'broken links' to merit mutual interest. In both cases the modelling must proceed on *a posterio* information about real-life properties of a network. The modelling of a past communication system and the planning of a contemporary logistics network might work on quite similar, basic parameters, including transport topography, demography, measured traffic loads, available modes of transport and their capacity—for which archaeological data may give useful proxies. Moreover, the problem presented by archaeology—to reconstruct the most likely flows reflected by these data—is sufficiently close to that of proposing optimal designs to warrant that an application could provide predictive models of considerable interest.

Network optimization algorithms present computer modellers with a worthy challenge: to generate predictive models from archaeological datasets, and to test outcomes against further observations. As with any form of complex modelling, however, the results may not be easy to assess. In the nature of complex modelling, it may be difficult or impossible to assess how a particular combination of basic conditions informs the outcomes, and hence what confidence can be placed in end results. Providing the generous margin of error within which archaeologists need to operate, it may be no less difficult to validate if predictions correspond to observations. If, as is only too often the case, the intermediate steps are not apparent, modelling entails a risk of providing black-box solutions to black-box problems.

Modelling based on formalized data easily neglects a vital component of the archaeological record. Whatever volume of data is synthesized in a formal analysis, its coding is likely to discard an even more substantial amount of detailed, contextual information. Most forms of archaeological reasoning involve close reading of individual pieces of evidence, which is almost impossible to reduce to a mere matrix: observations on the context of occurrence, morphology, and use of artefacts, and on the sites and assemblages in which they are found. Observations arising from a single context or object may provide crucial context for the interpretation of wider patterns, and sometimes supply self-evident answers to what would be difficult or arbitrary steps in a purely formal analysis. This form of data must be brought to bear on the modelling process.

## 4.4 THE EGO NETWORKS OF STEATITE VESSELS

To illustrate the complex processes that go into the formation of an archaeological artefact distribution, and which may sometimes be unravelled from careful, contextual study, we can look at the distribution of a single type of artefact. What our example demonstrates is that a full interpretation of the process of dispersion of any single artefact distribution is likely to involve a number of virtually separate networks. It also shows that although these components will not be apparent from a mere matrix of occurrence, there can be ways of inferring important characteristics.

Cooking vessels carved from steatite are among the archaeological signatures which trace the expansion of Scandinavians into the British and North Atlantic islands in the Viking period (9th–11th centuries AD). This is a well-defined and highly distinctive artefact type, which has been closely studied across all their areas of occurrence (Fig. 4.1).

Steatite, or soap-stone, is a soft, finely textured rock, found over wide areas of the North European mountain zones. It occurs abundantly in Norway, western Sweden, the Shetlands, and in Greenland, with some sporadic outcrops in mainland Scotland and Ireland (Resi 1979: 116). In regions where it is common, it was worked since prehistory for purposes including casting moulds, net sinkers, spindle whorls, and cooking vessels. For the last use in particular, it gained a high prevalence in parts of Scandinavia in the last centuries of the first millennium AD. Characteristically, the word for cooking pot in Old Norse (and in various reflexes in modern Scandinavian languages) is *grýta* derived from *grjót*—'stone'.

During the ninth century, in pace with the westward maritime expansion of Scandinavians, round-bottomed steatite vessels acquired a distribution into regions which had no natural supplies of the raw material. In Denmark, where no steatite vessels are testified before year 800, they are found in almost every major excavated settlement from the following two centuries (Risbøl 1994; Sindbæk 2005, 2009). A similar dense distribution follows after settlement in Iceland and the Faroese Islands where, however, access to the material may have become scarce after the initial 9th century *landnám* phase (Forster 2006: 64; Fitzhugh and Ward 2000). In central Sweden, however, steatite vessels are only found in major centres of exchange. This may partly be explained by the distance by sea from sources. Yet access to active steatite quarries in western Sweden was available via lake systems, and had these vessels been in the same demand as in Denmark, they should have merited the journey.

In both Denmark and the North Atlantic islands the vessels were acquired as an item of long-distance import. While the North Atlantic settlers were undoubtedly accustomed with their use before the move, populations in Denmark actively adopted stone pots as a cultural innovation. In Atlantic

**Fig. 4.1.** Distribution of round-bottomed steatite vessels in Northern Europe *c.* AD 800–1050. See text for data. Map: Author.

Scotland, Scandinavian settlers brought in Norwegian steatite vessels, but they also began to exploit outcrops in Shetland to set up a local industry (Buttler 1989, 1991; Forster 2004).

Outside the Northern Isles the Scandinavian migrants, who settled in the British Isles, readily adopted local alternatives to steatite vessels. Only in towns and other hubs of long-distance communication do we find a sporadic occurrence. In the 'Viking' towns of York and Dublin, detailed analysis shows that vessel morphologies including rim decoration patterns are 'recognizably Norwegian', rather than from the closer Shetland source (Forster 2006). Soot marks and wear-traces prove that the vessels were in long use, and there are no examples of rough, unused vessels that could indicate a direct importation for exchange (Mainman and Rogers 2000: 2541ff.). This suggests that the pots arrived as the personal possessions of visitors from steatite-using regions, rather than being allocated for a continued use as daily-life objects by settlers, or as prestige goods associated with Scandinavian origin and identity (Sindbæk in press). A similar pattern is suggested by the sporadic occurrence of steatite vessels in Eastern Europe, which is limited to major ports along the Baltic coasts and Russian rivers (Khvoshchinskaya 2007; Sindbæk 2009).

A network model to account for the distribution of steatite vessels would need to operate with a number of independently working mechanisms of dispersal. In Norway steatite bowls were a local product, quarried within the regional environment. Their distribution marks cultural emulation between neighbouring communities. In Denmark they were adopted through exchange, arguably as prestige items. By contrast, the vessels appear to have been rejected in central Sweden, possibly marking a boundary between cultural identity groups. In the Norse colonies in the North Atlantic they were brought in by the migration of Scandinavian settlers as part of their established culture. In Shetland steatite outcrops were found and local industries commenced in emulation of the Norwegian products. Further afield in the British Isles, the Baltic Sea region, and even in Russia, isolated finds occur in trading places where they can be taken to mark individual travel including commercial shipping.

I have dwelt on these details because they show how much can be gathered regarding communication networks from careful, archaeological study involving observations on materials, morphology, and wear, chronology, and context. These particulars, sometimes highly context-specific 'footnotes', like decoration, soot marks, or the absence of freshly carved, unused items, allow us to confirm or reject broader models and to place the finds in a sequence of dynamics.

This form of contextual understanding must set the bar for any meaningful application of network analysis to archaeological assemblages. Instead of approaching distribution patterns as arbitrary matrices, we need to highlight the cultural and economic practices and dispositions, which generated patterns, and which may help us to assess their significance and implications.

## 4.5 CONTEXTUAL NETWORKS SYNTHESIS

While detailed observations form an indispensable basis for archaeological analysis, they are a complement to formal analysis, rather than an alternative to it. A comprehensive discussion of dozens of find groups across numerous sites—no matter how elaborately presented—is unlikely in itself to provide an analyst with a balanced view of structural patterns across those sites and source materials. It is even more unlikely to enable other researchers to validate claims for such patterns, hence potentially leaving effectively unfounded, or worse (albeit not entirely unfamiliar in archaeology) to be statements based on the authority of the researcher. Here lies the appeal of formal analysis and modelling to enable structural comparison across complex datasets.

The modes of statistical analysis and visual representation associated with network analysis offer excellent ways of exploring and representing global properties of archaeological data. Short of producing a formal network synthesis, they provide a way of assessing specific questions concerning the structure of the evidence, which forms a necessary precondition for such a synthesis. If properly framed, they present a way of inferring the 'shape' of a network.

The discussion above highlights some observations. The clusters of steatite vessels in particular regions and sites speak strongly against a purely random mode of dispersal (as might be suggested, for instance, by an evenly diminishing frequency of finds relative to the distance from sources; cf. Renfrew 1977: 86). The 'lumpy' supra-regional distribution shows that interactions must have included long-distance movement (a fact also borne out in some cases by the mere distance over sea between finds and sources). Given the complex set of mechanisms which had to be evoked in order to explain the dispersals patterns, it is unlikely that the structure of communication involved in this displacement corresponds to any pure network form, such as a hierarchy or a set of virtually separate cycles. We must be dealing, hence, with an interconnected network in which non-random structures reflect particular roles assumed by certain nodes and links.

Further questions to be asked regarding the 'shape' of this long-distance communication network concerns the nature of the 'special' sites, links, and roles: can we identify separate classes of sites and links with exclusive roles, or do differences merely express relative variation in importance? Do special roles arise because certain sites are more 'popular' and attract a proportionally higher number of links (e.g. the Barabási model of a 'scale-free network'; cf. Albert and Barabási 1999), or more specifically because some sites attract particular *kinds* of links (e.g. a 'backbone/tributary' system of separate trunk routes and local links; cf. Klincewicz 1998)?

To assess these questions we may compare further artefact distribution networks in the wider North Sea region in the same period as steatite vessels

were mainly distributed; i.e. in the 10th century AD. To simplify the case we can start by limiting the comparison to other cooking pots. It was suggested above that the geographical outliers in the distribution of steatite vessels were likely to be items brought by long-distance travellers from steatite-using regions, and that such travellers targeted a selective group of sites. It remains to be seen if other travellers did the same.

In most regions of 10th-century northern Europe where people did not employ steatite vessels for cooking, they used ceramic vessels for the same purpose. Particular forms and styles of vessels are characteristic of particular regions, and can be recognized as non-local products when found elsewhere. Being objects of comparable character and use, it can be assumed that they followed travellers in more or less similar ways. Although some were presumably made by craft specialists and marketed over some area, none of them were luxury items likely to have entered into wider chains of circulation.

A pottery vessel, however, is a complex network of technological and cultural choices. Many traits can be transferred freely between regions and traditions, or arise independently in several places. Early medieval pottery in the North Sea region cannot be readily subsumed to a precise, exhaustive classification, though comprehensive surveys exist at regional or national level (McCarthy and Brooks 1988; Piton 1993; Lüdtke and Schietzel 2001; Hincker 2006, Young et al. 2006). Initial hopes that ceramic petrology could lead to an unambiguous sourcing of vessels to a region of origin or even to individual kiln sites have turned out to be impeded in many regions by a complex glacial geology (Vince 2005: 221).

Currently there is no way to detail the full associations of pottery assemblages across wider regions in terms of simple, directional links from a site of occurrence to a site of origin. What may be achieved is to chart broader affiliations through particular combinations of typological dimensions (fabric, technology, shape, decoration), which, when taken together, are sufficiently robust to be identified as genuine affiliation groups (i.e. items which are closely related by origin). This approach can be thought of as tracing individual 'currents' in a pool of overlapping material and stylistic characteristics. Vessels identified in this way will not necessarily be produced in a single site, but they will express close cultural affinity in a network of production and consumption.

Based on criteria such as those outlined above, we can identify a series of general types of vessels, each of which characterize a broad region. In north and east England the typical 10th-century cooking vessel is a Thetford-type pot (the suffix '-type' denoting the broad inclusion of similar products from other production sites than Thetford). These are wheel-thrown, kiln-fired, mostly finely sand-tempered, reduced grey earthenwares. Typical Thetford-type cooking pots are globular with sagging base and outward-turned rims, and are often decorated with roulette stamping and with fingertip impressions on

rim. For the purpose of unambiguous identification the fingertip impressions, which are rare in other regions, are regarded here as a defining characteristic.

Thetford-type wares were presumably introduced in England by potters from continental Europe, as cooking pots in the Frankish regions (from the Rhine towards the Seine) have quite similar shapes, and are also wheel-thrown, kiln-fired, and finely sand-tempered. They can be distinguished, however, by their colour, being typically oxidized rather than reduced, and by the frequent use of black or red painting. 10th-century vessels from the Rhineland typically have wavy-line or 'leopard-spot' painting (early Pingsdorf wares), while French and Belgian pots are more likely to have geometrical designs. The latter are also distinguished from the former by having flat bases.

Outside these regions, typical cooking pots were hand-built and fired at low temperatures. While vessel morphology is more varied than in wheel-thrown wares, it is possible to distinguish some traits as characteristic of regional traditions: In the Irish Sea region, several wares are characterized by grass-marked bases; in Friesland and the Netherland coasts we find globular, shell-tempered vessels ('Muschelgrus ware'); typical vessels from the Slavic areas in the Baltic Sea coasts of Germany include flat-bottomed vessels with straight or slightly inwards-turned rim and with comb-point and wavy line-incised ornaments on the upper half of the pots ('Fresendorf ware').

The above is a highly selective and simplified list of wares within the area of study, and it often lumps more detailed local typologies together. It does, however, present a balanced selection of products, which are typical within particular geographical regions, and which can be clearly recognized in published reports.

Together with steatite the occurrence of these six wares are charted in a selection of 152 published settlement assemblages in Norway, Sweden, Denmark, Germany, Belgium, the Netherlands, and the United Kingdom, plus selected comparative sites in France, Ireland and Poland (Fig. 4.2). For each country the number of sites selected corresponds relatively to existing estimates of population densities (high in fertile lowland regions, much lower in highland regions; cf. Benedictow 1996), aiming for one site per 50,000 estimated inhabitants. Where a choice is available, larger and more diverse assemblages are preferred to smaller and less diverse ones.

The association between these artefact types and the selected sites is illustrated in the graph Fig. 4.3, produced with the network-analysis programme Pajek (Nooy et al. 2005). Artefact types (black dots) are linked to the sites in which they occur (white dots). The layout of the graph is energized (using the Kamada-Kawai algorithm) to show the relative proximity of relatedness between vertices. Both sites and artefact types can be seen to cluster in certain groups.

A large number of sites link only to a single type of artefact and form discrete clusters along the rim of the graph. While some of these sites are likely


**Fig. 4.2.** Map of settlement assemblages selected for study. For details, see note 1. Map: Author.

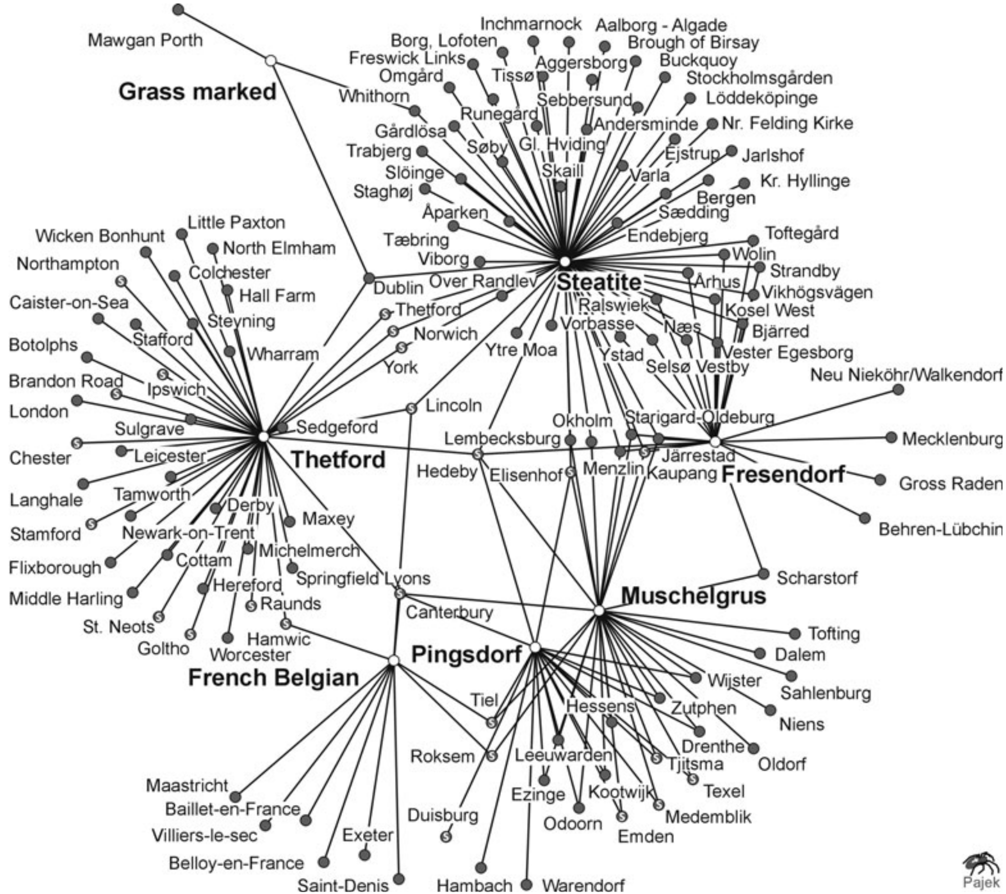


**Fig. 4.3.** Graph of the associations of seven different types of cooking pots in 152 settlement-site assemblages from the 10th century in the North Sea region and adjacent areas. Sites in which large storage jars ('ampora') are recorded are marked by 'S'. Graph produced by author using *Pajek*.

to be small or poorly-recorded assemblages, the majority are from well-investigated sites with more than 1,000 recorded sherds; the absence of any but local types of cooking pots is therefore likely to reflect real trends. In the outer parts of the area of study the distribution is biased by the fact that neighbouring regions and their vessel types are not charted. This may be the case in particular for sites in the Baltic Sea area and in France and Germany. Sites in these areas may appear more peripheral than they would if an even wider area was included in the study. Sites in the southern and western parts of the British Isles may be biased by the very limited use of ceramic vessels in these regions. However, the absence of local pottery could equally have been an incentive for non-local visitors to have brought and used their own vessels on a more significant scale than elsewhere, as was the case in Kaupang, Norway (Hougen 1993: 9). The rarity of non-local wares in these regions is therefore likely to reflect a genuinely low frequency of non-local visitors to the recorded sites.

Sites with more diverse assemblages appear in the middle of the graph. Just as there can be a variety of explanations for a scarcity of types, there can be several reasons why a site yields more than one type of ware. In regions where distributions overlap, or where easy coastal navigation facilitates transport, the presence of several wares in sites may result from regional rather than long-distance interaction. This may be the reason why the distribution of Fresendorf ware integrates with steatite vessels in many sites in the Baltic Sea region. While this articulation should clearly be seen as evidence of inter-regional communication, it is reasonable to conclude that it represents a more general and less specialized integration than, for example, the co-occurrence of steatite vessels and Thetford-type pottery in sites in England.

Regardless of these uncertainties, sites that gain centrality in the graph through having other than local domestic wares might be expected to have a particular role in long-distance communication.

This can be demonstrated by drawing yet another type of vessel into the comparison: storage jars. Sites with storage jars are shown in the graph Fig. 4.3 as a special partition, marked by 'S'. Large storage jars, or amphoras, were produced both on the Continent ('Reliefband-amphora') and in north-east England. Both types are recognized by applied clay bands used to decorate and strengthen the vessel. They were generally used for storing and handling goods, and hence have a functional association with transport and/or exchange. Where such jars were produced in regional kilns their distribution sometimes reaches rural sites (e.g. Goltho or Raunds) in addition, of course, to kiln sites (e.g. St. Neots, Brandon Road, Ipswich, or Stamford). In the Baltic and Irish Sea areas, on the other hand, they appear to occur only as a result of direct sea transport from the areas of production. Even so, virtually all sites with a diverse assemblage of cooking pots are also sites with storage jars. This high degree of correspondence would suggest that these were generally sites with a special role in long-distance communication.

The evidence yields further clues as to how communication was organized between sites within the core group. In the graph Fig 4.4 affiliations have been remodelled from a two-mode network (sites and artefacts) to a single-mode one (sites only), in which links between sites express joint affiliation; i.e. the presence of one or more shared artefact types. In order to suppress random connections only links with a combined strength of two or more shared artefact types are included, and sites with only a single recorded vessel type have been removed. By remodelling the data in this way it is possible to calculate the relative centrality of each node. This measure is based on 'betweenness'; i.e. the ratio by which a given node forms part of all the shortest possible chains between any two other nodes in the network, an indication of the importance of that node in the global network structure (Nooy et al. 2005: 131ff.).

The reduced network consists of a limited number of core sites, sometimes historically famous towns and cities. Still, the links between these should not

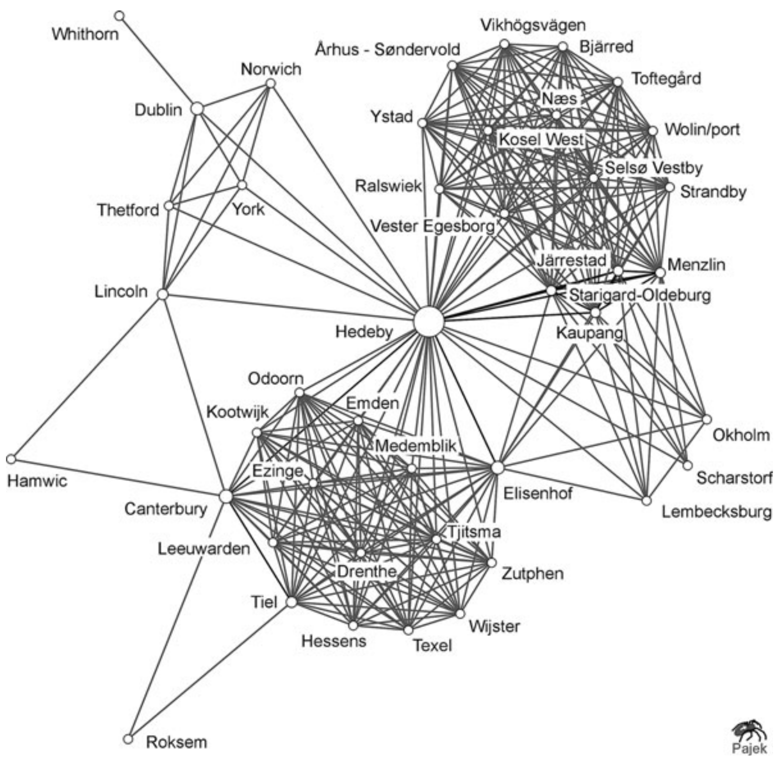


**Fig. 4.4.** Remodelling of the former network. Sites with less than two artefact types are omitted, and affiliations are represented as a single-mode (sites only) network in which links indicate two or more shared artefact types. Graph produced by author using *Pajek*.

be mistaken to indicate a measure of direct communication. They express general affiliations, and connect any pair of sites in which a shared artefact type occurs. Moreover, the selection of recorded assemblages does not include every major site which was active in long-distance communication. Any patterns observed will concern regional trends in long-distance communication, rather than routes between the specific sites indicated.

The graph indicates that artefact distributions do not connect core sites in all regions equally. It is possible to recognize a 'wrath' of links connecting English sites to continental ones, continental sites to Scandinavian ones, and so forth. We can recognize the basis for this pattern in the former graph: steatite vessels arrived in key sites in England and in south Scandinavia, but not on the Continent. Thetford-ware occurs on along the southern coast of the Continent, but not, it seems, beyond Hedeby. Sites which appear at the intersection of these clusters are marked by a high 'betweenness' centrality; for example Dublin or Canterbury. Assemblages from the latter site are so distinct from other English sites that it becomes more closely affiliated with Continental ones. Hedeby forms a virtual bridge between North Sea and Baltic Sea affiliations, as indicated by its exceptionally high 'betweenness'.

The rarity of finds pointing to communication beyond neighbouring pottery regions suggests that the centres to which long-distance travels were mainly directed also acted as 'filters' for communication further afield. While the evidence presented here is too limited and coarse-grained to substantiate the point, this may suggest a segmented system through which long-distance communication was not only directed *to* selected sites but generally passed *from* these to other similar sites. This pattern generated a system of intermediate trunk segments, which combined to form a ring along the coasts of the North Sea area. Judging by the artefact distributions, then, these trunk segments would carry the bulk of long-distance interactions, forming a 'backbone' structure in the communication network.

## 4.6 CONCLUSION

The case study discussed in this chapter demonstrates how formal network analysis can be combined with a contextual reading of evidence relating to a long-distance communication network in the past to make inferences about the structure and dynamics of that network. The inter-related distributions of a range of vessel types identify a separate class of sites with a particular role in long-distance communication. This role is not entirely exclusive to these sites, and hence does not express a pure hierarchy of communication, yet it does not merely express a relative variation in 'popularity'; i.e. that some sites attract a

proportionally higher number of links. Rather, a particular kind of link was preferably directed to specific sites.

The 'backbone' of long-distance travel was attached to particular nodes, from which more localized interaction tended to issue as tributary systems. Trunk routes did not connect central sites equally, but formed a segmented system of links between selected nodes. In this way we are able to suggest a plausible outline of the core structure of the long-distance communication network, as a ring of route segments passing between sites along the coasts of the North Sea area. The central sites in this network are typically urban centres, and predominantly sites with privileged access to maritime traffic.

The model proposed here is in no way a groundbreaking or controversial interpretation of the pattern of long-distance communication in the North Sea area in the 10th century, but aligns well with general assumptions among historians and archaeologists specializing in the area (Schofield and Vince 2005: 153; Lebecq 2007). Network analysis, however, provides better substantiation to patterns suggested by rare written documents or inferred on the basis of traditional archaeological analysis of assemblages or distribution maps.

The patterns noted in the artefact distributions might presumably have been demonstrated without recourse to network graphs. It should be noted, however, how the graphs clarify global patterns in a way which could not have been achieved equally well with the help of tables, distribution maps, correspondence matrices or bar graphs. Simple statistical measures calculated using standard tools of network analysis highlight patterns, which could otherwise be difficult to appreciate, and thus facilitate interpretation. In this manner, network analysis and visualization prove their value as tools of validation as well as exploration.

These points underline the more general objective of this paper, which is to suggest that the 'black-box' problem of archaeological network synthesis—the problem of reconstructing structural properties of a ruined network from inferences about its performance—is not beyond the reach of archaeological study. Viable approaches based on formal computational modelling can be suggested, although solutions obtained in this way will remain probabilistic models subject to further confirmation. 'Black boxes' can be persuasively negotiated, however, by combining formal network analysis with contextual interpretation. Applied in this way, network synthesis and network analysis have the potential to become valuable tools for exploring, validating, and demonstrating observations about communication in the past.

## NOTE 1

Settlement assemblages consulted for the case study. For sites in Denmark and Sweden the published data is supplemented by information gathered from

museum records and collections. Bibliographical references are to the main or most recent source, in which reference can be found to further reports. For lack of space the references are not cited in the bibliography, but all can be traced in common online academic bibliographical databases.

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# 5

# Positioning Power in a Multi-relational Framework

## A Social Network Analysis of Classic Maya Political Rhetoric

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SUMMARY

This study suggests that a multirelational analysis of archaeological networks can be used to infer the dynamic interaction between the agency of polities or rulers and the power structure of a region. However, making sense of the disparate and low-density ties based on the epigraphic record requires models that simplify these socio-matrices. The concept of structural equivalence allows us to identify a model of the social network, which partitions these relations into collections of polities that occupy similar positions. The resulting images of this model reveal the often complex roles that the Classic Maya polities created.

### 5.1 INTRODUCTION

Social network analyses are uniquely suited to address questions about the interplay between structure and agency. Although there remains significant scholarly debate regarding the recursive interaction between structure and agency in archaeology (Dobres and Robb 2000; Dornan 2002; Hegmon 2008), these are theoretically well-developed and familiar—if not also debated—concepts that are relevant to the social sciences more broadly (Sewell 1992). In

archaeology, discussions have focused on how agents (e.g. individuals, households, societies) employ variable degrees of intentionality to achieve selected goals as they reproduce and transform their social worlds (Dornan 2002; Varien and Potter 2008); however, considerably less attention has been paid to the structural roles of political and economic institutions as constraining or facilitating choices, actions, and decision making. For our purposes, we view structure and agency not in terms of a dichotomy (Moore 2000), but rather as inseparable parts of a single process (Giddens 1979: 53, 69–70; Joyce and Lopiparo 2005).

Despite theoretical arguments on the structure/agency debate in archaeology, few seem concerned with developing a more cohesive methodology including analytical tools to evaluate these common social phenomena (cf. Dobres and Robb 2005). Several scholars have proposed refocusing on collective or relational agency as a way to position individual actions in a larger social field (Dornan 2002; Hegmon 2003; Varien and Potter 2008). Hegmon (2008: 219) also emphasizes the importance of considering multi-scalar linkages, and we extend this to include both the spatial and social domains. In this chapter, we suggest that social network analysis offers a methodology and set of analytical tools to operationalize notions of structured agency. By outlining a network-based approach that emphasizes relations between entities as the unit of analysis, we consider the ways that structure, agency, and power articulate and cross-cut diverse political and geographic boundaries. To demonstrate this approach we examine how different rhetorical statements characterize the political strategies of Maya rulers and contributed to the definition of political boundaries in the Classic period. In this chapter we suggest that political manoeuvring and power-building strategies can be empirically evaluated by focusing on the ways that Classic Maya rulers positioned themselves and expressed their relationship to others through the documentary record.

## 5.2 PREVIOUS RESEARCH

Carved stone monuments provide one of the primary sources of information on Classic Maya political history. Maya rulers recorded many of their political achievements, social relationships, and dynastic lineage on monolithic slabs of carved limestone that were often placed in plazas and in front of temple buildings at Classic Maya centres. These stelae also often recorded calendric dates associated with these statements. In conjunction with archaeological data, previous studies have used these texts to examine political organization from various perspectives (Carmean and Sabloff 1996; Chase and Chase 1996; de Montmollin 1995; Folan 1992; Fox 1988; Fox and Cook 1996; Fox et al. 1996; Marcus 1976; Martin and Grube 1995; Pohl and Pohl 1994; Webster 1997). In

particular, Simon Martin and Nikolai Grube have made substantive contributions to our understanding of Classic Maya dynastic history by compiling one of the most comprehensive syntheses of the hieroglyphic record (Martin and Grube 2000, 2008). Others have similarly chronicled the political histories and dynastic relations between notable social actors for the Classic period (Houston 1993; Johnston 1985; Mathews and Willey 1991; Schele and Friedel 1990; Schele and Mathews 1991). Such detailed narratives are the foundation for unravelling sequences of events at Classic Maya centres, but elucidating broader patterns of institutional change has not been the focus of these historical reconstructions. In a recent study we used these dated and inscribed monuments to reconstruct multirelational social networks between Classic Maya centres and chart organizational changes between antagonistic, diplomatic, lineage, and subordinate relations through time (Munson and Macri 2009). Our research builds on this earlier work, but here we focus on how these relations contribute to actors' social position in the network by comparing the rhetorical strategies employed by political elites and assessing these narrative accounts of history with quantitative techniques developed in social network analysis.

## 5.3 STATEMENTS OF POWER

This study interprets the inscriptions recorded on Classic Maya stone monuments as distinct expressions of political power. Although this is one specific context in which power is expressed, we recognize that power is part of all social relations and exists only when it is exercised or put into action by individuals or groups of people (Foucault 1982; Lukes 1978). Classic Maya rulers commonly sponsored the carving of a monument to celebrate particular events associated with a given dynastic rule: accession to political office, taking of captives, and rituals associated with calendar endings. Inscriptions on these monuments also recorded relationships between the king and subsidiary lords or polities as well as familial relationships. We argue that the prevalence of certain types of statements reflects different political strategies employed by Classic Maya rulers. At Copan, for example, dynastic rule was legitimized by tracing one's ancestry to the founder Yax K'uk Mo' as documented on Altar Q (Fash and Stuart 1991; Stuart 2005). Other centres such as Yaxchilan mainly exercise power through subjugation, while others employ bellicose tactics. Together these inscriptions represent the rhetorical style of each ruler or polity and their attempts to establish and maintain positions of power within Classic Maya society. The rhetoric expressed in these monuments, however, is represented by multiple statements of political propaganda that lend authority to existing structures of control. As such, it is important to point out that these

inscriptions are seldom impartial, but are selective statements that may have been edited for particular political or religious affect (Houston 1993: 94). The veracity of these statements cannot be taken at face value, but require careful evaluation and understanding that they may reflect a biased view of the past; indeed, there is little mention of non-royal individuals in Classic Maya texts (cf. Jackson 2005; Zender 2004). Nonetheless, the way in which rulers make claims about themselves and others is an indication of strategic manoeuvring and it is through these varied pathways that rulers positioned themselves.

## 5.4 NETWORKS IN ARCHAEOLOGY

Social network analysis is a methodology that can address the dynamic interplay between actors using varying tactics and the structured domains in which they operate. This perspective offers a way to examine the consequences of particular network structures in terms of the kinds of interactions they facilitate. Various techniques have been developed in sociology to analyse the nodal and structural properties of social networks (see Wasserman and Faust 1994). In this study we employ the concepts of social position and social role to analyse social networks comprising many actors connected by multiple types of ties (White et al. 1976). Social position can be defined as 'a collection of actors who are similar in their relations with others' (Faust and Wasserman 1992: 6). For instance, teachers have similar ties with students regardless of the subject matter being taught or the school that facilitates these educational exchanges. Social roles are defined as 'systems of relations among actors or positions' (Faust and Wasserman 1992: 6). Rather than sociological constructs, roles are concepts that relate to categories that we recognize in everyday language. This concept can be illustrated by kinship roles, which incorporate multiple relations such as fatherhood, marriage, or brotherhood. For instance, relations of marriage and brotherhood are captured by the term 'brother-in-law'. Similarly, the role of grandfather describes the father of a father, a role combining a relation with itself (Wasserman and Faust 1994: 249). Thus, a relation is simply a 'collection of ties of a specific kind among members of a group' (Wasserman and Faust 1994: 20), such as the documented subordination statements that connect primary and secondary Classic Maya centres. This should not be confused with the notion of a relationship or a tie, however, which connects two actors, as in a statement of subjugation made by Yaxchilan over Piedras Negras. Social network analysts have developed a variety of methods to identify and describe concrete social structures from complex networks with many actors and multiple relations (White et al. 1976).

### 5.4.1 Archaeological Applications

As this volume and recent research demonstrate, social network analyses offer archaeologists a set of methods that can be used to address questions about the relationships between actors. Most commonly, basic descriptive statistics of actors, such as their centrality, are calculated based on the number of ties an actor has or the average number of ties it takes to reach all other actors. These measures have recently been chosen in a handful of network applications in archaeology because they fit with common archaeological conceptions of actors (usually households or sites) as independent from one another. For instance, some recent network applications to archaeology focus on the centrality of sites, in order to address questions about early state formation, social hierarchy, and political centralization (Mizoguchi 2009). Other archaeologists have used historic documents to create networks from past travel itineraries of routes between points in the Roman Empire (Graham 2006), and by long-distance exchange and the travels of a Christian missionary in Viking Scandinavia (Sindbæk 2007a, 2007b). Other studies use prehistoric travel networks to understand archaeological similarities between prehistoric sites (Smith 2005), but more importantly look at the role of trade and exchange in the development of settlement structure (Sindbæk 2007a, 2007b), and the past experience of landscape (Graham 2006).

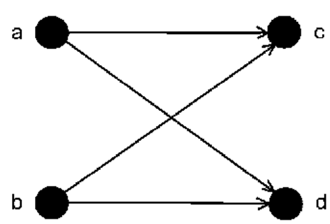
Network measures that describe individual nodes can also be generalized for the whole network. Recently, these measures have been applied to describe past social networks based on archaeological data. The concept of cohesion, defined as the strength or frequency of ties, is used to compare an observed network with one in which all nodes are connected to each other in order to examine the way that social network structure could influence cultural diversity and diffusion, for instance (Graham 2006). Centralization indices can also be used to describe the general connectedness of actors in a network (e.g. Munson and Macri 2009). Other approaches to past socio-political organization can compare network structure to known or idealized structures, like random networks, to examine the size and distribution of prehistoric settlements (Hamilton et al. 2007; Kohler et al. 2000). These approaches generally characterize the adjacency matrix used to describe the ways that actors are tied to one another in each relation.

## 5.5 POSITION, ROLE, AND STRUCTURAL EQUIVALENCE

Social network analysis can also be used to model the ways that agency and social structure intersect through analyses of position and role in multiple relations. However, few archaeological studies (cf. Scholnick 2010) have

explicitly taken a relational approach to networks, and examined the social position of actors or their roles using the concept of *structural equivalence*. Structural equivalence occurs when two or more actors share the same ties with others (Lorrain and White 1971). This approach identifies positions, or subsets (also termed blocks) of actors who are similarly embedded in networks of relations (Wasserman and Faust 1994: 347). Position describes the ways that actors are similarly connected to others in the network. This is not based on actors' adjacency, proximity, or the makeup of a cohesive subgroup, but rather defines the ways that groups of individual actors relate to one another in a complex system of relations. The social distance between two actors is defined not as the path distance or number of ties that connect two actors, but rather in terms of the shared elements between actors in the overall network (Burt 1976: 94). In this sense, structural equivalence can be operationalized as a metric used to identify positions.

The analysis of role and position in a social network has two complementary goals: to identify actors that share similar positions in the network, and to describe the ways that relations are combined to associate actors and positions (Wasserman and Faust 1994: 351). Positional analysis is based on the concept of structural equivalence, where actors can be substituted for others in the network without altering the topology of the network. Positions are comprised of actors that have similar ties in one or more relation (Fig. 5.1). The most accurate description of social position is based on more than one relation, because people are tied to each other in many different ways in reality (Lorrain and White 1971; White et al. 1976: 739). Structural equivalence in its strict definition, however, is a rare occurrence, particularly in networks with many actors, where the chance of two actors sharing the exact same set of ties with




| | a | b | c | d |
|---|---|---|---|---|
| a | 0 | 0 | 1 | 1 |
| b | 0 | 0 | 1 | 1 |
| c | 0 | 0 | 0 | 0 |
| d | 0 | 0 | 0 | 0 |

**Fig. 5.1.** An illustration of Lorrain and White's (1971) definition of structural equivalence, showing that nodes a and b are equivalent because they have identical ties to other nodes, c and d.

others along multiple relations is less likely (Lorrain and White 1971). This concept is therefore commonly relaxed in order to measure the similarity between actors' ties with others in the network. Role analysis also considers the patterned ways actors and social positions are related to each other in the network through combinations of relations. Social network analyses of role structures in the network examine similarity in the algebras of actors, or how they interpenetrate multiple relations (see Boorman and White 1976; Breiger and Pattison 1978). Ideas about social role can be examined systematically using algebra to manipulate social network relations, each expressed as matrices, in order to identify the social roles that crosscut a complex system of relations.

Actors can be partitioned based on the similarity of their ties in order to identify those that occupy the same position in a social network. Social network analysis has developed a method of partitioning structurally equivalent actors by reordering the rows and columns of a socio-matrix to order members of each block next to each other (White et al. 1976: 739). A socio-matrix, $x_{ij}$, is a matrix where each element represents the presence or absence of ties from one actor to another actor, $i \rightarrow j$. The goal of a positional analysis is to partition the matrix in order to identify positions where the actors are tied to each other (1s), and actors that are not tied to each other (0s). This is called a *blockmodel* because these partitions, or blocks, create rectangular submatrices of cells each of which is ideally filled largely with zeroes or largely with ones (White et al. 1976: 739). A given partition of a socio-matrix, or blockmodel, is one of many possible hypotheses about the positions of a social network based on their ties with each other, not based on attributes of the actors (White et al. 1976: 731). The lack of ties between positions is as important in defining blocks as the occurrence of dense ties between actors. These are referred to as *one-blocks* and *zero-blocks*; however, a one-block is not always saturated with ones. The absence of some ties in a one-block can be explained by a number of possibilities: the result of sampling error, failure of subject to disclose all ties, the fact that some of these ties within a position are redundant and unnecessary or the group may not, in fact, be saturated with ties such that all actors are linked to others (White et al. 1976). Sociomatrices can be reduced to their constituent zero- and one-blocks to represent the ties between blocks, providing an image of the overall structure of the network.

## 5.6 METHODOLOGY

Networks can be represented as a matrix representing each relation, or type of tie between actors. In order to identify positions in a multi-relational network, actors' ties in each relation can be considered simultaneously. However,

identifying social positions among many actors in multiple relations is challenging, but can be addressed using methods of data reduction to identify actors occupying similar positions. In order to perform a positional analysis, a socio-matrix, $x_{ijr}$, representing each relation, $X_r$, and its transpose, $x^{T}{}_{jir}$, are stacked so that occurrence of ties between actors can be correlated (White et al. 1976). With $R$ relations, the resulting set of stacked matrices, each of size $g \times g$, is a rectangular array with $2R \times g$ rows and $g$ columns (see Wasserman and Faust 1994: 371). While perfect structural equivalence is indeed rare, correlations between actors indicate the degree of structural equivalence between two actors (Wasserman and Faust 1994: 365).

Cluster analysis is commonly used to identify the positional similarity of actors based on the correlation matrix. There are many different clustering algorithms that can be used, but one that is preferred in multi-relational blockmodelling is hierarchical clustering using a complete linkage algorithm (see Aldenderfer and Blashfield 1984), which identifies partitions where all pairs of actors are no less similar than other pairs (Padgett and Ansell 1993; Wasserman and Faust 1994). This method groups clusters additively, rather than divisively as other methods, like CONCOR (White et al. 1976). The resulting blockmodel can be represented as a reduced image matrix or a graph that represents the blocks, revealing the types of ties both within and between positions. An image matrix summarizes the ties between and within positions as ones or zeroes representing the ties between actors in each of these positions (Wasserman and Faust 1994: 390). The presence or absence of a tie between positions can be defined by different rules often based on the density of ties between actors in these positions. These images of the blockmodel reveal important structural characteristics of the network along each different relation.

An important aspect of blockmodelling is assessing the adequacy of the partitions that are identified. The adequacy of the reduced image matrix to describe the full dataset must be determined (cf. Padgett and Ansell 1993), which can be assessed by comparing the density of each block or the proportion of ties that are included by the blockmodel. Since the positional analyses of networks are not based on parameterized probability distributions, using standard parametric statistics to determine fit is not appropriate (Wasserman and Faust 1994: 676). Two methods are commonly used to evaluate the appropriate fitness of a blockmodel: evaluating the block membership with respect to attributes of the actors (e.g. Padgett and Ansell 1993), or stochastic methods that compare the observed positions with random partitions of the network (Baker and Hubert 1981). While both of these methods are viable, few archaeological data sources complement the epigraphic record. This study uses a method of randomizing adjacency matrices for each of the relations and comparing the variance within the block partitions with the total sum of squares (Noma and Smith 1985). If a block is completely composed of ones

or zeroes indicating perfect structural equivalence, the variance within the partition is zero and the R-squared is high.

This study also investigates the role of spatial structure in social position. While one might assume that adjacency in a socio-matrix is related to geographical distance between actors, positional similarity is based on the ties that actors have with others. Although they may have similar ties with actors that are geographically close, this is not necessarily the case. To examine the spatial structure of actors' ties, we can compare the correlation matrix with a distance matrix using a QAP procedure (Baker and Hubert 1981). Correlations between structural equivalence measures and spatial weight matrices with incremental distance lags indicate the spatial structure of social network ties.

## 5.7 MAYA HIEROGLYPHIC DATA

The corpus of Maya hieroglyphic inscriptions contains rich information about the lives of kings and political histories of Classic Maya centres. While this data does not provide scholars with the detailed economic transactions of noble families (cf. Padgett and McLean 2006), the Classic Maya epigraphic record does offer insights into the political strategies employed by the ruling elite. This study uses epigraphic data from the Maya Hieroglyphic Database to investigate the structural equivalence of sites that record statements of political affiliation during the Classic period. The Maya Hieroglyphic Database (MHD) is a digital repository of transcribed and transliterated Classic Maya writing and is intended ultimately to include all published texts inscribed on known monuments, architecture, books, and other portable objects (Macri and Looper 1991–2009). When this analysis was conducted, over 40,000 glyph blocks were catalogued in the database representing a large sample of the known Classic period texts. Linguists, archaeologists, and art historians have utilized this rich resource to investigate a range of topics pertaining to Maya languages (Macri and Looper 2003, 2009; Vail 2000; Vail and Macri 2000).

For our purposes, this dataset provides detailed information on political relations between sites based on the appearance of emblem glyphs. These standardized glyphs are common occurrences in the epigraphic record and are composed of three signs: a prefix (*k'uhul*), a superfix (*ajaw*), and a main sign used to identify a particular kingdom ruled by the named *k'uhul ajaw* or holy lord (Berlin 1958; Mathews 1991; Stuart and Houston 1994). The main sign also occurs by itself and is used more generically to refer to particular places or other people from those polities. A number of other categories of place names

have been identified in the corpus of Maya hieroglyphic writings (Tokovinine 2008), but this study employs the traditional usage of emblem glyphs as representative of specific kingdoms. Following an earlier study by Munson and Macri (2009), we identified all instances of these place-name glyphs in the database, classifying them as site names, toponyms, site titles, and emblem glyphs. In the majority of cases, place-name glyphs occur in local contexts—that is, sites employ self-referential statements using their own emblem glyph to record events and rulers associated with their own dynastic history; however, the appearance of foreign place-name glyphs is also common (Table 5.1). These cases provide us with important information about the ties between Classic Maya centres.

We catalogued the statements in which all place-name glyphs occurred according to a two-tiered classification schema (Table 5.2). Seven categories describe the different relations within the network. These categories have been adapted from previous studies (Martin and Grube 2000; Schele and Mathews 1991) and are defined by the presence and transcription of specific verbs or nouns occurring in conjunction with the place-name glyph. For example, the verb **ch'ak** *ch'ak* precedes the emblem glyph designating Copan on Stela J at Quirigua and is used in reference to the beheading of the great Copan king Waxaklajuun Ub'aah K'awiil. Antagonistic relations are characterized by such bellicose statements, but may also refer to events from slightly different perspectives, as when Copan records the demise of Waxaklajuun Ub'aah K'awiil by 'flint and shield' indicating a noble death in battle (Martin and Grube 2000: 205). Although referencing the same event, these statements have vastly different connotations for interpreting history and exemplify the rhetorical saliency of these texts. Antagonism may also be reflected through subjugation as when referring to captives and the guarding of prisoners as was common at Yaxchilan and Dos Pilas (Golden et al. 2008; Houston 1993; Schele 1991). In contrast, statements of diplomacy represent amicable relations that were often forged through ceremonies such as the commonly cited 'scattering' rite. Ceremonial gatherings may also be indicated by the verb

**Table 5.1.** Counts of statements by category and the relative frequency of non-local statements, defined as those that reference another polity, included in this network analysis

| CATEGORY | TOTAL | NON-LOCAL (%) |
|---|---|---|
| Kinship | 56 | 37.50 |
| Subordination | 104 | 38.46 |
| Diplomatic | 115 | 40.00 |
| Antagonistic | 173 | 46.24 |
| Dynastic | 259 | 3.47 |
| Unknown | 303 | 25.41 |
| Neutral | 534 | 8.61 |
| TOTAL | 1544 | 20.66 |

**yi-ta-ji** *yitaj*, which conveys some meaning of 'presence', 'together with' or 'his companion'. In addition to recording historical events, these inscriptions also provide information on social relations. Dynastic lineage statements frequently refer to the accession of rulers which was repeatedly celebrated at Palenque using the verb forms **k'al-ja-hun** *k'alaj hun* **joy?-ja ti ajaw-le** *joyaj ti' ajawlel*, **and chu-mu-wa-ni** *chumwan*, which all refer to various rites associated with taking political office (see Table 5.2)—the latter of which may be spatially and/or temporally restricted and has important implications for this study (see Hruby and Child 2004). Although the inscriptions include fewer statements about kin relations, the majority of these are found in the western lowlands suggesting that these centres expressed a unique rhetoric. Hierarchical relations between rulers and their subordinates are another common occurrence in the corpus of hieroglyphic writing. For example, the title **sa-ja-la** *sajal* denotes a provincial governor or subsidiary leader who was subordinate to the holy ruler, *ch'uhul ajaw*. The majority of place-name glyphs in this sample can be classified as neutral because they simply modify the name of an inscribed ruler referring to his dynastic kingdom. Most of these statements are self-referential, but are nonetheless important to defining the blockmodel. While the place-name glyphs are common and relatively easy to identify, in many instances the surrounding glyphs may be indiscernible due to erosion or because they have not yet been deciphered. These unknown contexts were excluded from the present study so that only those place-name glyphs modifying a definite social relation or interaction between two sites were analysed. Although the blockmodel is defined based on the presence and absence of ties, the total count and frequency of these relations are recorded in Table 5.1.

This network represents a sample of Classic Maya sites that recorded statements of political affiliation on stone monuments. The total dataset is composed of fifty-one sites and 1544 statements. Since we are interested in the way polities position themselves relative to one another within this network, we only included sites that recorded at least one foreign place-name glyph; sites that only referred to themselves were excluded. Hieroglyphic writing appears on a variety of media, but we only included inscriptions made on stone and wood stelae and lintels since it may be difficult to determine the original producers or owners of portable objects like painted cylinder vases. In addition, only stelae from sources with authoritative provenance were included in the study. Notably absent from our dataset are the majority of inscriptions from Calakmul, which have proved troublesome for epigraphers to decipher due to poor preservation of the monuments. Fortunately, several sites in Campeche and across the southern lowlands refer to Calakmul (Grube 2005, 2008), providing us with numerous indications about what kinds of relations this centre established with others. Nonetheless, we must recognize that this missing data may bias our interpretations of this particular blockmodel

**Table 5.2.** Classification schema of theme and contextual statements employing place-name glyphs

| THEME | TRANSLITERATION | CH'OLAN | ENGLISH GLOSS |
|---|---|---|---|
| Antagonistic: hostile relationships involving subjugation | | | |
| | **u(-cha?)-chan(-nu)** | *uchan?* | 'his guardian' (+ captor's emblem) |
| | **u(-cha?)-chan(-nu)** | *uchan?* | 'his guardian' (+ captives' emblem) |
| | **ya-te-a** | *yate'ah?* | 'prisoner' |
| | **pul-yi, pu-lu-yi** | *puluy* | 'burned' |
| | **hub'?-yi** | *hub'uy?* | 'fell' |
| | **chu-ka-ja** | *chukaj* | 'was captured' |
| | **u-na-ka-wa** | *unak-wa* | 'attacked' |
| | **u-ch'ak(-ja)** | *ch'ak* | 'attacked, cut' |
| | **ya-la-ja** | *yalaj* | 'threw him' |
| | **ja-tza-ja** | *jatzaj* | 'was hit' |
| | **yäl** | *yäl* | 'throw down' |
| | **el** | *el* | 'burns' |
| | **tok' pakal** | *tok' pakal* | 'his flint his shield' |
| Diplomatic: non-hostile, friendly relations often involving ritual practice | | | |
| | **yi-ta-ji** | *yitaj* | 'together with' |
| | **ye-te(-he)** | *yetel* | 'by, with' |
| | **yi-chi-nal** | *yichnal* | 'in his company' |
| | **pi-tzi-ja** | *pitzaj* | 'played ball' |
| | **(yi-)il(-li)** | *il* | 'witnessed' |
| | **chok ch'aj** | *chok ch'aj* | 'scattering' |
| Dynastic lineage: sovereign relations | | | |
| | **chum-wa-ni ta ajaw-le** | *chumwan ti ajawlel* | 'was seated in ajawship' |
| | **joy?-ja ti sa-ja-li** | *joyah? ti' sajal* | 'acceded as sajal' |
| | **ik hun?** | *ik' hun* | 'takes the headband' |
| | **ajawyan** | *ajawyan* | 'accession' |
| | **joy?-ja ti ajaw-le** | *joyah? ti' ajaw* | 'acceded as ajaw' |
| Kinship lineage: familial relations | | | |
| | **ya-al(-la)** | *yal* | 'her child' |
| | **u-nich?** | *unich?* | 'his child' |
| | **ya-tz'i/xu?-na** | *??* | 'his mother' |
| | **ya-ta-na** | *yatan* | 'wife' |
| Subordination: hierarchical relationship involving subjugation | | | |
| | **ya-ha-wa, ya-ajaw** | *yajal* | 'his ajaw' |
| | **sa-ja-la** | *sajal* | 'noble title' |
| | **u-kab'-hi(-ya)** | *ukab'i/ukahi* | 'under his authority' |
| Neutral: impartial, equitable relationship often in the local instance when none of the other criteria are present | | | |
| Unknown: indiscernible due to erosion, decipherment, or lack of information | | | |

The theme category represents seven different types of sociopolitical relationships identified and analysed in this and previous studies (see Munson and Macri 2009). For a detailed discussion of the glyphic representation and comparison of these relationships see Macri et al. (2009).

so we discuss possible alternative scenarios below. Although the data included in this study represent a large sample of Classic Maya inscriptions, with additional entries, new archaeological discoveries, and advances in decipherment, the interpretations drawn in this study are apt to change. Our objective then is not necessarily to propose a new model of Classic Maya political organization, but rather to evaluate how a multi-relational network approach can be applied to archaeological data to investigate the ways past social actors positioned themselves in dynamic political landscapes.

## 5.8 RESULTS

The blockmodel presents a parsimonious model of Classic Maya political organization as described in the epigraphic record. This analysis identifies positions based on the statements these actors make about themselves and other actors, as well as references to them in texts written by other actors. In these contexts, self-referential statements are important rhetorical devices deployed by rulers to legitimize their position of authority among the local population, but in our discussion we focus on the relations and statements made between actors. The blocks are thus composed of sites that share similar positions based on these statements and are named according to the major site in each block (Fig. 5.2). In the following discussion we discriminate between inter- and intra-block relations by referencing sites by their name and blocks according to a two or three-letter code representing the major site in each block (Table 5.3).

A parsimonious blockmodel of a social network has somewhere between 1 and n positions, where n is the number of actors in the social network. This analysis identifies a blockmodel that partitions the fifty-one polities selected from the MHD into sixteen blocks with between two and six members. Although there is no way of knowing how many partitions represent the best model of the data, we performed a goodness-of-fit test using a homophily model, which indicates that block membership is significant.[1] Two sites (Altar de Sacrificios and Chinikiha) are not highly correlated with others in the network, and can be considered either unassigned or in blocks by themselves. Block assignments can be based both on ties between actors (adjacency) and similar ties with other actors that occupy a

[1] Goodness-of-fit was assessed using a QAP procedure (Baker and Hubert 1981) implemented in the UCINET software package (Borgatti et al. 2002). Using a homophily model, which assumes that actors are more likely to have ties within block than between block, the block assignments were compared with each of the six relations used in the analysis. Each of the R-squared values is significant at the p=0.001 level.

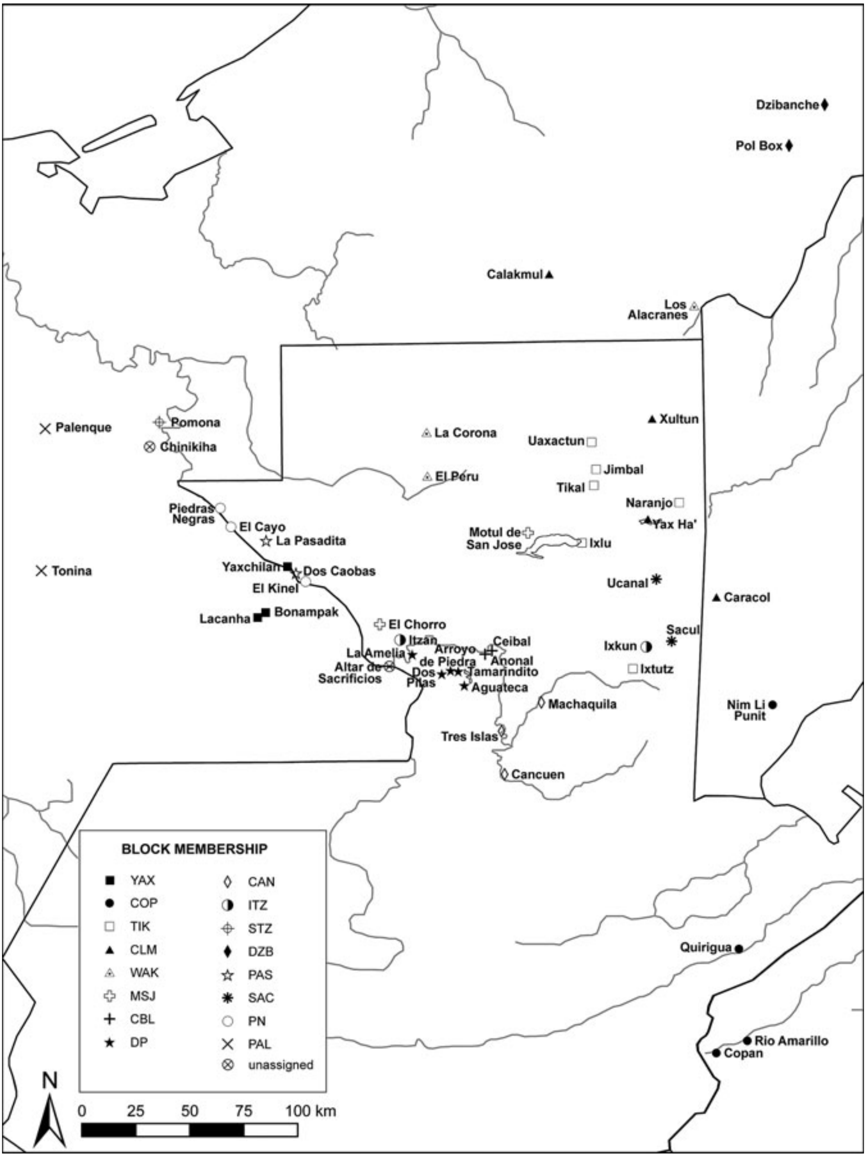



**Fig. 5.2.** Map showing the location of Classic Maya sites included in this analysis. Block membership is identified by symbol and semi-groups are named according to the major site in each block (see Table 5.3).

**Table 5.3.** List of sites by block with major site identified in bold

| Block name | Sites |
|---|---|
| CAN | **Cancuen** |
| | Tres Islas |
| | Machaquila |
| CBL | **Ceibal** |
| | Anonal |
| CLM | **Calakmul** |
| | Xultun |
| | Yax Ha' |
| | Caracol |
| COP | **Copan** |
| | Rio Amarillo |
| | Quirigua |
| | Nim Li Punit |
| DP | **Dos Pilas** |
| | Aguateca |
| | Tamarindito |
| | Arroyo de Piedra |
| | La Amelia |
| DZB | **Dzibanche** |
| | Pol Box |
| ITZ | **Itzan** |
| | Ixkun |
| LAP | **La Pasadita** |
| | Dos Caobas |
| | Laxtunich |
| | Site R |
| MSJ | **Motul de San Jose** |
| | El Chorro |
| PAL | **Palenque** |
| | Tonina |
| PN | **Piedras Negras** |
| | El Cayo |
| | El Kinel |
| SAC | **Sacul** |
| | Ucanal |
| STZ | **Sak Tz'i'** |
| | Pomona |
| TIK | **Tikal** |
| | Uaxactun |
| | Jimbal |
| | Naranjo |
| | Ixlu |
| | Ixtutz |
| WAK | **El Peru-Wa'ka** |
| | La Corona |
| | Los Alacranes |
| YAX | **Yaxchilan** |
| | Bonampak |
| | Lacanha |
| unassigned | Altar de Sacrificios |
| | Chinikha |

different social position. Not all blocks in this model have dense internal ties between polities, and few blocks have extensive ties with other blocks. The most striking aspect of this model is how the blocks differ in their rhetoric, which differentiates positions in this multi-relational social space. We discuss the contributions of each relation to block membership and then test the hypothesis that geographic distance is a structuring factor.

### 5.8.1 Antagonism

Some polities preferentially used statements describing conquests or conflicts to demonstrate their power (Table 5.4). The polities within the DP block commonly used antagonistic statements to refer to other polities in the block as well as polities in other blocks. The DP block made antagonistic statements when referring to four other blocks, including the CAN, CBL, MSJ and YAX blocks. The major sites in these blocks also commonly made antagonistic references to other block members, as five of twenty-five of the possible ties between these sites are characterized by at least one antagonistic statement. Yet only one statement about the DP block's aggression is made by another position (CBL block). This is a unique instance in the epigraphic record where the capture and sacrifice of a king is recorded at the defeated centre. In this case, it seems likely that scribes from DP were commissioned to inscribe these statements on Ceibal's Hieroglyphic Stairway as they identify the new Ceibal lord as subordinate to Dos Pilas (Mathews and Willey 1991: 50). In addition, it seems that antagonism was an important theme of the inscriptions in the YAX block. Not only are bellicose statements made between sites in the YAX block, but as a whole this block is also antagonistic with the CAN and PAL blocks.

### 5.8.2 Subordination

Subordination statements commonly refer to sites within the same block, indicating hierarchical relationships, but subordination statements between blocks suggest that some sites more aggressively pursued dominant positions. Two blocks preferentially use subordination statements both within and between blocks: CLM and YAX (Table 5.5). Many sites employ statements of subordination to Calakmul, indicating this centre's prominence in the Classic Maya world (Martin and Grube 2008). Unfortunately, deciphered and published texts from Calakmul are unavailable so it is not possible to determine whether this dominant centre referred to its subordinates in the inscriptions, although we can infer much about Calakmul's position from these non-local references. No fewer than six blocks make subordination statements in

**Table 5.4.** Image matrix of the antagonistic relation based on a lean fit criterion, where elements of this matrix with the value 1 represent at least 1 tie between positions

| | CLM | CAN | CBL | COP | DP | DZB | ITZ | LAP | MSJ | PAL | PN | SAC | STZ | TIK | WAK | YAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLM | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| CAN | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CBL | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| COP | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DP | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| DZB | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ITZ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| LAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| MSJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| PN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| SAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TIK | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| WAK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| YAX | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 5.5.** Image matrix of the subordinate relation based on a lean fit criterion, where elements of this matrix with the value 1 represent at least 1 tie between positions

| | CLM | CAN | CBL | COP | DP | DZB | ITZ | LAP | MSJ | PAL | PN | SAC | STZ | TIK | WAK | YAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLM | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| CAN | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CBL | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| COP | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DP | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DZB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ITZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| LAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| MSJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PAL | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| PN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| SAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TIK | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| WAK | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| YAX | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |

reference to the CLM block, including CAN, DP, WAK, PAL, TIK, and YAX. Within the CLM block, there are very few instances of sites referencing one another as subordinate. In contrast, the YAX block consistently makes subordination statements about other blocks (CLM, PAL, PN, and TIK). In addition, the members of the YAX block make many subordination statements about each other (four of a possible nine statements).

### 5.8.3 Diplomacy

Ceibal holds a unique position in this social network, with extensive diplomatic references to other sites (Table 5.6). Ceibal describes foreign emissaries from Calakmul, Dos Pilas, Tikal and around the western Lake Itzan region attending ceremonies at this centre to celebrate various period-endings. Most famously, Stela 10 from Ceibal describes the *katun*-ending celebration of 10.1.0.0.0 with a scattering event (*chok* MZS) administered by Ceibal's Terminal Classic ruler and three attendees identified by the emblem glyphs of Tikal, Calakmul, and the Ik' site. The distance travelled by these foreign representatives suggests this was a particularly special ceremony marking the first period-ending of the tenth baktun. Few other sites reference so many other blocks in this capacity. The PN block also cites diplomatic ties with the STZ and YAX blocks, but ritual participation among these centres may have been more common since these sites are located near each other. While the CLM block is most commonly identified in subordination statements, it is also referenced four times in diplomatic statements by other blocks (CAN, CBL, DP, and WAK). It is noteworthy that Cancuen, Dos Pilas, and El Peru-Wa'ka also make subordination statements to CLM when its emissaries attend these ceremonial events.

### 5.8.4 Kinship Lineage

A previous study identified kin-based lineage as a particularly centralized network that contributed significantly to changes in network centralization (rCI) over time (Munson and Macri 2009). In this study we have refined our definition of lineage, differentiating between dynastic and kinship relations. As noted previously, the structure of the kinship network is quite different from other relations (Table 5.7). These statements are most commonly made about local rulers from the same site, but also occur in some frequency within blocks. YAX was one of the few blocks to use kinship to establish ties with other positions. The kinship image suggests the YAX block may have used familial ties to establish connections with other blocks, such as CLM and CAN (see Table 5.7). In addition, WAK and LAP cite kinship ties with YAX. Kinship ties figure more

**Table 5.6.** Image matrix of the diplomatic relation based on a lean fit criterion, where elements of this matrix with the value 1 represent at least 1 tie between positions

| | CLM | CAN | CBL | COP | DP | DZB | ITZ | LAP | MSJ | PAL | PN | SAC | STZ | TIK | WAK | YAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLM | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| CAN | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CBL | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| COP | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DP | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DZB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ITZ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| LAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MSJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| PN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| SAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| STZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TIK | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| WAK | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| YAX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 5.7.** Image matrix of the kinship lineage relation based on a lean fit criterion, where elements of this matrix with the value 1 represent at least 1 tie between positions

| | CLM | CAN | CBL | COP | DP | DZB | ITZ | LAP | MSJ | PAL | PN | SAC | STZ | TIK | WAK | YAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CAN | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CBL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| COP | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| DP | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DZB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ITZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| MSJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| PN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| SAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| STZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TIK | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| WAK | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| YAX | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

prominently within blocks. For instance, members of the YAX block have relatively dense kinship ties with each other (four of nine possible ties).

### 5.8.5 Dynastic Lineage

Dynastic statements are overwhelmingly self-referential (see Table 5.1). While the matrix of dynastic lineage statements is not very dense, most statements are within blocks, and very few describe dynastic ties between blocks (Table 5.8). The few notable instances of between-block dynastic references include DP and WAK which cite dynastic ties to CLM. It is also noteworthy that these two examples occur in tandem with statements of subordination and diplomacy, pointing to the overlapping role structure of this social network.

When examining the ties between sites and between blocks, dynastic lineage statements could be overlooked because they are largely self-referential statements rulers made to position themselves in the local dynastic history. Rarely do these statements link sites in other blocks. However, other relations are more evenly balanced with ties between polities in the same block and polities in other blocks. Twice as many diplomatic, kinship lineage, and neutral statements, reference polities in the same block than polities in another block (Table 5.9). Subordination statements within blocks roughly equal the number of statements made between blocks. However, the reverse is true with antagonistic relations because between block statements account for nearly twice as many statements as within block statements.

### 5.8.6 The Spatial Hypothesis

There are few alternative lines of evidence with such comprehensive coverage that we can use to identify similarities between the social positions of Classic Maya kingdoms. One hypothesis for grouping sites is based on their spatial proximity, assuming that nearby sites are more likely to interact with each other. While this Classic Maya social network was structured by space, structural equivalence does not always overlap with spatial proximity. Some blocks are commonly comprised of polities that are close to each other, as with those along the Usumacinta and the Pasión rivers, or with the Copan block, but others are not clearly based on spatial proximity. In fact, this analysis considers the neighbouring sites of Yaxchilan, Dos Caobas, and El Kinel, in different positions of the social network (see Fig. 5.2). Other studies have demonstrated that the terminal monument dates at Classic Maya sites are spatially autocorrelated (Bove 1981; Kvamme 1990; Neiman 1997; Premo 2004; Whitley and Clark 1985). While many have asked how and why the terminal monument dates are spatially dependent, few have specifically

**Table 5.8.** Image matrix of the dynastic relation based on a lean fit criterion, where elements of this matrix with the value 1 represent at least 1 tie between positions

| | CLM | CAN | CBL | COP | DP | DZB | ITZ | LAP | MSJ | PAL | PN | SAC | STZ | TIK | WAK | YAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLM | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CAN | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CBL | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| COP | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DP | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DZB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ITZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MSJ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| PN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| SAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TIK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| WAK | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| YAX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 5.9.** Counts of within and between block ties by relation

| Relation | Within Block | Between Block |
|---|---|---|
| antagonistic | 18 | 31 |
| diplomatic | 29 | 16 |
| dynastic lineage | 26 | 2 |
| kinship lineage | 19 | 9 |
| neutral | 32 | 16 |
| subordination | 23 | 20 |

The counts represent the presence of a directional tie between two polities. These counts do not represent the number of statements made between polities.

addressed how the textual references between sites are dependent on space. We use the correlation matrix based on six themes identified above to ask how social position is related to spatial distance.

The geographic proximity hypothesis does not fit with our model of structural equivalence based on these relations. Under the geographic proximity hypothesis, we expect the correlation between structural equivalence measures and spatial weight matrices. However, polities less than 20 kilometres apart show lower structural equivalence than sites that are 30 to 120 kilometres distant (Fig. 5.3). This is not to suggest that sites less than 20 kilometres apart were not interacting

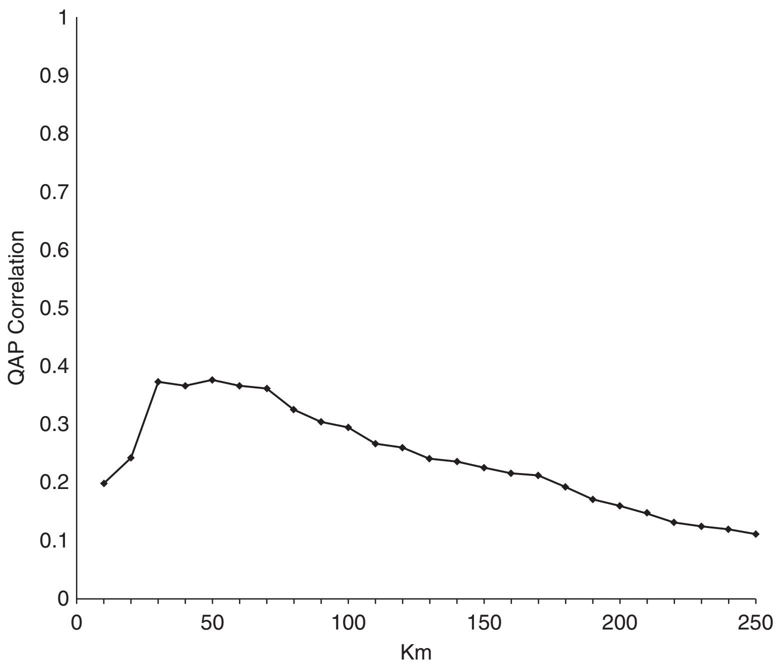



**Fig. 5.3.** QAP correlations between structural equivalence measures and spatial weight matrices at increasing 10 km lags suggest that polities between 30 and 70 km apart exhibit the greatest positional similarity.

with each other; rather, these relationships are not captured using the concept of structural equivalence. The greatest degree of correlation between the social positions of Classic period centres occurs between 30 and 70 kilometres. This indicates that while neighbouring polities may indeed have a great deal of interaction with one another, Classic Maya polities are not likely to refer to such close neighbours in the inscriptions. It is worth noting that the concept of structural equivalence identifies social positions based on similar ties with other polities, even though positions may be defined by close interactions between actors in the same block.

## 5.9 DISCUSSION

The positions identified by this multi-relational analysis capture the varied rhetorical strategies employed by Classic Maya rulers. Several centres invested heavily in monument dedication with texts stating their social position in the Classic Maya world, or at least their view of it. This analysis describes the diverse strategies that dynasties used, including various combinations of conquest, subjugation, diplomacy, kinship, and dynastic lineage, in those documentary records. While some centres, like Ceibal, participate in diplomatic affairs and ceremonies with foreign representatives, others, like Dos Pilas, engage in more bellicose rhetoric, boasting of conquest and capture. Still other centres position themselves by describing their subjugation of or subordination to other polities. Although the epigraphic record concerning Calakmul is primarily comprised of statements made by others, it is clear that positions in the social network can be defined by subordination to Calakmul. Importantly though, more nuanced strategies can be inferred from the image matrices of these relations. Calakmul also sent representatives to ceremonies at Ceibal, Cancuen, and El Peru, and had kinship ties with El Peru and Cancuen. We also see multiple overlapping relations in the inscriptions documenting Yaxchilan's political history. Yaxchilan describes subjugating the PAL and PN positions, and in turn they cite Yaxchilan's presence at ceremonies. Furthermore, the LAP block is defined by both antagonism with and subordination to Yaxchilan. The multiple overlapping roles that define the positions of CLM and YAX point to complex strategies to build and maintain power over other Classic Maya centres.

The social positions defined by the blockmodel reveal a perspective of Classic Maya political organization different from most regional studies using Classic Maya inscriptions. Of course, not all relationships between sites, particularly those between neighbours, are recorded in the epigraphic record. This analysis only captures those relationships between sites that have an emblem glyph and make reference to at least one other centre. The spatial analysis suggests that polities are more likely to describe similar social ties if they are located between about 20 and 70 kilometres apart. In some cases, a regional analysis of

archaeological sites may find a block of polities that occupy a similar social position, but this study cautions that spatial proximity should not be equated with similar social position. This analysis suggests that Classic Maya rhetoric and political strategies consist of simultaneously referencing one's own dynastic pedigree while also describing ties with distant powerful centres.

While traditional prose accounts of the inscriptions identify similar relationships between centres, this positional analysis facilitates comparison between sites that may not make direct statements or reference one another in the epigraphic record. Given the sometimes sparse and patchy nature of the archaeological record, this technique holds unique promise for identifying patterned similarity that may otherwise go undetected. Furthermore, this analysis provides a rigorous methodology to quantify archaeological patterning and evaluate traditional narratives based on historical reconstruction.

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# 6

# What Makes a Site Important? Centrality, Gateways, and Gravity

*Ray Rivers, Carl Knappett, and Tim Evans*

## 6.1 INTRODUCTION

Analysing patterns of spatial organization is one of the most basic procedures for any archaeologist. This is relevant across all spatial scales, from the household to the region, particularly as expressed in some of the most formative texts of processual archaeology (e.g. Flannery 1976; Clarke 1977). As the focus of this volume is regional interaction, we will here consider questions of spatial organization at the macro scale.

Whether this concerns the distribution of sites, or the distribution of materials/artefacts, archaeologists have tended to work from a certain set of understandings about inhabited space, in particular in terms of zones of interaction around a material source or central site (cf. Smith 2005). For example, for many years archaeologists have used Thiessen (or Voronoi) polygons to tessellate regions containing known sites (e.g. see Conolly and Lake 2006). This can provide a sense of site importance if, in the process, it emerges that some sites have influence over larger domains than others. It is also possible that larger sites can subsume smaller ones. In particular, the related XTENT model allows larger sites to exercise an influence that will spread across the boundaries of smaller neighbours (Renfrew and Level 1979).

In these approaches, in which spatial organization is conceived in a 'radial' manner (Jennings 2006), the 'power' of a centre—whether derived from a high concentration of people, or material—naturally lends itself to similes in terms of 'forces'. Thus tessellation methods suggest important centres as 'pushing' their influence towards their neighbours' boundaries. In this chapter we shall present the complementary viewpoint that sees important sites as sources of *attraction* for 'trade', technologies, and ideas, 'drawing in' from the same and further neighbours. We stress that these approaches are not necessarily

antithetical since they may represent different categories of interaction; e.g. what we might loosely term socio-political and socio-economic. Even within the latter the 'push' from one site's zone of influence upon its neighbour's may have much in common with the 'pull' on the site by its same neighbour. For this chapter we prefer to think entirely in terms of directional interactions between sites rather than complicating matters by inferring zones of influence.

Just as with tessellations, our main goal is to find workable criteria for what makes a site an important centre of attraction, and secondly, to test them for a system for which we have a good archaeological record. It is clear that we cannot just use site size alone, since the importance of a site is also related to its interactions and position with respect to other sites. These can often be characterized as reflecting the site's 'centrality'. Centrality can take many different forms and exist for many different reasons. Do we mean a centre of population, a centre of agricultural redistribution or a centre of a trading network? For example, one kind of centre may be a 'central place' or a 'hub', and yet another a 'gateway' (Hirth 1978; Hodges 1982; for Early Bronze Age Aegean, see Branigan 1991). Arguably, archaeologists have not given nearly enough attention to the different kinds of centres that may exist, and more importantly, our means for identifying them. This chapter takes a step towards remedying this by considering centrality in greater detail, to the exclusion of other measures of importance.

If, to this end, we are going to both shift away from a 'zonal' understanding, and recognize the specific kinds of directional links that might exist between sites, then what methods are available? Network methods are eminently suitable (see Smith 2005) for providing measures of centrality. Yet perhaps because of the prevalence of zonal thinking discussed above, they have been relatively under-utilized in archaeology. In the 1970s, as archaeology came under the influence of the New Geography, there was some sporadic use of networks, both to analyse trade patterns (e.g. Irwin-Williams 1977), and to assess centrality, with the use of graph theory on data from coastal Papua New Guinea (Irwin 1974, 1978). It is difficult finding other uses of networks for regional analysis from this period, and we have to leap forward a decade to the work of Peregrine (1991), distinguishing between degree, betweenness, and closeness centrality in analysing the role of Cahokia in the Mississippi river system, and Gorenflo and Bell (1991) on how one might use network analysis to assess ancient road systems. Also at this time we find Broodbank (1993; see also 2000) inspired by the work of Irwin and colleagues (e.g. Terrell; Hunt) in Papua New Guinea and Oceania to assess interactions in the Bronze Age Cyclades using proximal point analysis (see also Hage and Harary 1991).

Despite the sporadic nature of most of these appearances of network analysis, the theme of centrality does seem to be a recurring one. In the one area where networks have been more consistently applied, Oceania (see Terrell this volume), centrality is one of the main features measured on the networks

under analysis. So it should perhaps not come as too much of a surprise that in the recent return to network studies in archaeology, centrality again features prominently. Munson and Macri (2009) in their work on Maya networks based on epigraphic data also draw on Freeman in their focus on degree centralization; Isaksen (2008) uses betweenness and closeness centrality measures; Johansen et al. (2004) discuss degree and 'information' centrality; Mizoguchi (2009) uses a wider range of centrality measures (for which see Jackson 2008; Newman 2010).

As we see from these examples, networks can arise in several different contexts, with details conditioned by geography, exchange technology (e.g. modes and ease of exchange), social organization, to say the least. Although there are some generalities, this conditioning is sufficiently explicit to require that their application has to be tempered to specific questions, concerning societies of a particular time and place. With this in mind we have chosen the Middle Bronze Age (MBA) southern Aegean, for which we have already developed network models (Evans et al. 2009, 2012; Knappett et al. 2008, 2011; Rivers et al. in press). As we have seen above, archipelagos are particularly suited to network analysis, since islands provide natural choices of network nodes and, with a dominant means of transport (in this case, sailing vessels), the links between the nodes are simplified. Further, the MBA Aegean, characterized by a strong Minoan/northern Cretan presence, is approximately isolated in space and time, beginning with the rise of the 'palaces' and concluding with their burning, sometime after the eruption of Thera.

If we want to quantify the centrality of a site we need to introduce metrics which may seem too specific and, on occasion, inappropriate, but which can be used as a basis for discussion. In the next section we shall recapitulate some of the basic definitions of centrality before using them in subsequent sections to show how different network approaches identify the 'centres', 'hubs', and 'bridges' of the MBA 'thalassocracy'.

## 6.2 WHAT DO WE MEAN BY CENTRALITY?

In the first instance, we consider centrality in the sense of a 'central place', as defined by Renfrew (1977: 85):

> *The central place is a locus for exchange activity, and more of any material passes through it (per head of population) than through a smaller settlement.*

This concept of 'central place' implies more than simply larger size, even though 'size' comes in several forms; e.g. in the carrying capacity of the site (its resource availability) and its resource exploitation (a possible proxy for population). We need to know how the site in question connects to other sites.

The archaeological networks we have in mind have sites connecting with each other in a variety of ways and with a variety of strengths, from the very strong to the very weak; the networks are *weighted*. Indeed, although we shall not pursue this here, the stability of many social networks is dependent on there being many weak links (Granovetter 1973, 1983). These bring in rare but necessary contacts, practices, and materials that enable innovation to thrive. Further, whatever the nature of the exchange, we do not expect exact reciprocity in the relationship between sites; the networks are *directed*. Each pair of sites is connected by two opposing links reflecting different levels of exchange. For non-directed networks, where the flows are identical we can, if we wish, replace the pair of links by a single undirected link.

For this reason we cannot talk simply of the 'degree' of a site—i.e. the number of links a site has to other sites, a conventional measure of centrality—as we can for simpler un-weighted, undirected networks, in which links of equal strength are either switched on or off (e.g. networks of citations, simple kinship). We suppose instead that we can identify a single measure that characterizes this inter-site exchange, small when the links are weak, large when they are strong. For the sake of argument we can think of it most simply as representing a flow of boats/goods and perhaps people, although we appreciate that there is much more to 'exchange' than this. The degree of a site can now be generalized to its *out-strength* or *outflow* (the total outward flow/exchange from the site to the other sites) and the *in-strength* or *inflow* (the inward flow from the remainder of the network).

Suppose the table of inflows and outflows is given by some means (we shall suggest several dynamical approaches for estimating it later). A sufficient reason for a site to be central in the sense of Renfrew is that the other sites have strong interactions with it. Whereas the *outflow* of the site is often limited, the *inflow* to the site is not. This suggests, as a first guess, that we rank sites by their inflows. The greater the influx, the higher we would rank the site. However, this first guess can be improved, in that site importance should be enhanced if the site is connected to sites that are themselves important. Thus, as a second guess, we can again rank sites by the inflows from the rest of the network, but in which each inflow is enhanced or diminished, according to the site rank of the origin of the flow as derived one step earlier. We can now repeat this procedure, using the new site rankings. On iterating the process, we converge to an unambiguous centrality ranking, the so-called *eigenvector centrality ranking* (Newman 2010).[1]

As we said earlier, in what follows we shall apply these ideas to Bronze Age Aegean maritime exchange. In a simple picture of island networks, harbours with high eigenvector centrality ranking will be the busiest, with the highest

[1] The ranks correspond to the components of the eigenvector with largest eigenvalue unity of the matrix whose elements determine the relative probabilities of exchange between sites.

numbers of goods arriving and leaving, or the most people passing through them. We shall just term this *rank*. Further, rank per head of population, which we term *impact*, is just Renfrew's measure of central places quoted earlier. Should there be sites with significantly higher rank than their neighbours, then they are understood as the 'hubs' of the network. These are not necessarily the busiest sites of the network as a whole, as defined by the ranking tables proposed above, but those that are relatively the busiest within a region or neighbourhood.[2] In practice, we shall not make much use of them.

*Rank* can be problematic for those strongly directed networks in which some sites have strong outward flows and weak or no inward flows. Not only do such sites have low rank, but sites that connect to them can acquire low rank by contagion. In these cases it is sometimes helpful to introduce a qualified centrality ranking which interpolates between site size and site rank. To do this, we give the sites an initial 'centrality' value proportional to their size by taking the complementary fraction of the incoming flows in determining final rank and iterate the procedure, as before. If we think in terms of journeys between harbours, we treat the network-wide activity as an aggregate of random exchanges/journeys, once the constraints upon them imposed by the model (e.g. distance, 'cost') have been taken into account. Whereas *rank* assumes perpetual travelling this qualified ranking effectively corresponds to giving a boat/traveller only a finite number of stopovers. Such a ranking is called *Katz centrality ranking*, and is the basis of *Google Page Rank*, used for ranking web pages. For the reasons given later we shall not find this ranking useful for our networks, although the concept is useful in helping to define other notions of centrality, in particular *betweenness centrality* (or, more simply, *betweenness*), which differ from that of Renfrew's 'central space' discussed earlier. A site with high betweenness may or may not have high rank or be a hub but, typically, could be an end of an important 'bridge' between parts of the network; a 'bridge' in the sense that, if it is broken, the connectivity of the network is damaged. It is understood as a measure of the influence a site has over the flows of people, goods, and information through the network, insofar as it lies on important exchange routes between central sites.

In general, one might imagine that the most important routes between sites are those that are most easily (or 'cheaply') traversed, which often will be among the 'shortest'. Unfortunately, in its simplest form, defined as the fraction of shortest paths between sites which pass through the site of interest, *betweenness* does not generalize simply to directed networks of variable exchange strength. Further, the assumption behind this definition, that

[2] There is a more technical definition of hub centrality that refers to sites whose outflows are to sites of high centrality (e.g. see Newman 2010). We have a much more colloquial understanding of hubs in mind.

exchange between sites follows the shortest routes, is unlikely to be true. The Late Bronze Age Ulu Burun shipwreck off the south coast of Turkey shows a passage in which cargo has been picked up and dropped off in anything but the shortest route. Although this is a different period and a different distance scale from that considered here we might expect something similar. With this in mind we adopt (and adapt to weighted networks) alternative measures of betweenness that relax the shortest-path condition to include all paths between sites, but which can be weighted so as to give emphasis to the shorter paths. They are manifestations of what Newman (Newman 2003) has termed 'random-walk betweenness'. If conventional betweenness corresponds to the targeted transmission of exchange (goods, people, etc.) by the shortest route, the latter assumes exchange by vessels with no clear long-distance goals.

Even then there are two very different approaches that we can adopt. Our approach is to estimate the likelihood for travel along all paths that connect separated sites allowing for a finite number of stopovers, as used in Katz centrality.[3] From these we can construct the flow through a given site that is a generalization of the number of shortest journeys through it, which takes some less directed travelling into account.[4] We might anticipate a good correlation between our betweenness centrality and what constitutes a central place—high rank goes along with high betweenness in many cases. Those sites with high betweenness can be thought of as 'gateways' if their relative rank is low, but we shall not be too prescriptive in our use of the term.

As we said in the introduction, our interest in these manifestations of 'centrality' is because they provide a sense of site importance that we expect to see reflected in the archaeological record. Exactly how is not clear but, among other things, we would expect sites with high rank to reflect this in the size of harbours, in the variety of artefacts and the technical innovation of production techniques. At a local level, hubs would show the same. Gateways are not necessarily large but, again, would expect to have their importance reflected in the variety of artefact types and the distances they may have travelled. In what follows we shall see how both central places and gateways arise in the MBA Aegean.

For the MBA southern Aegean of Fig. 6.1, we have identified the thirty-nine sites listed in Table 6.1 as some of the most significant. In later figures we shall

[3] There is an additional free parameter (as in Katz ranking), the number of stopovers in a typical journey, from one onwards. Once away from extremes the betweenness ranking is not usually sensitive to its choice. We take the number of stopovers to be 'a few'.

[4] This differs from Newman's approach in his 2005 paper, which ignores the equilibrium flows of the network, the steady buzz of activity as goods and people flow across the southern Aegean. He defines betweenness in terms of how the network behaves when we put it under pressure, imposing a 'push' from initial and final sites. In the terminology of eigenvalues, both this and our definition of betweenness use the information in the eigenvectors for non-leading eigenvalues, but Newman's ignores the leading eigenvector completely.

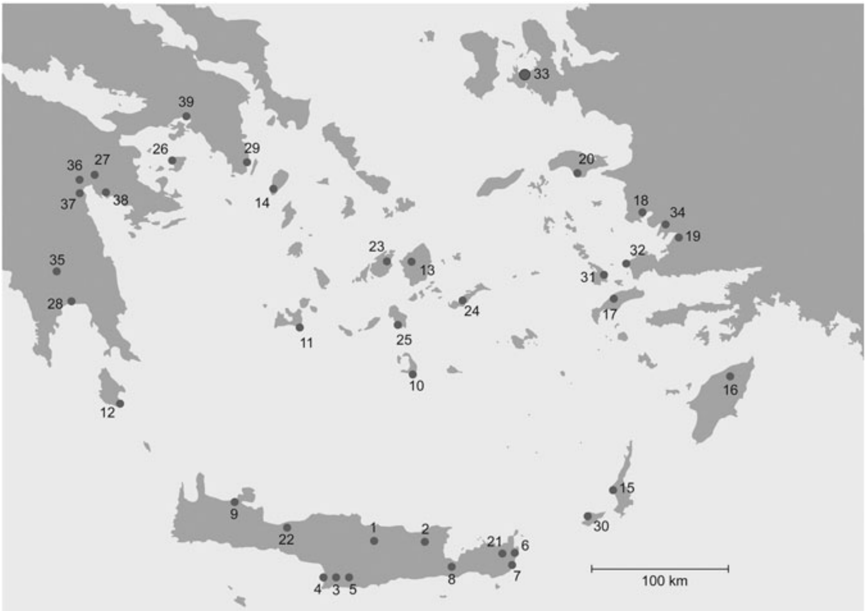


**Fig. 6.1.** Important sites for the MBA Aegean, including Knossos [1] and Thera [10]. The sea journey from the N. Cretan coast to Thera is just more than 100 km.

**Table 6.1** The sites enumerated in Fig. 6.1.

| | | |
|---|---|---|
| 1. Knossos (L) | 14. Kea (M) | 27. Mycenae (L) |
| 2. Malia (L) | 15. Karpathos (S) | 28. Ayios Stephanos (L) |
| 3. Phaistos (L) | 16. Rhodes (L) | 29. Lavrion (M) |
| 4. Kommos (M) | 17. Kos (M) | 30. Kasos (S) |
| 5. Ayia Triadha (L) | 18. Miletus (L) | 31. Kalymnos (S) |
| 6. Palaikastro (L) | 19. Iasos (M) | 32. Myndus (M) |
| 7. Zakros (M) | 20. Samos (M) | 33. Cesme (M) |
| 8. Gournia (L) | 21. Petras (L) | 34. Akbuk (M) |
| 9. Chania (L) | 22. Rethymnon (L) | 35. Menelaion (S) |
| 10. Thera (M) | 23. Paroikia (M) | 36. Argos (M) |
| 11. Phylakopi (M) | 24. Amorgos (S) | 37. Lerna (M) |
| 12. Kastri (M) | 25. Ios (S) | 38. Asine (S) |
| 13. Naxos (L) | 26. Aegina (M) | 39. Eleusis (M) |

show networks imposed upon these sites in which the thickness of the directed links reflects site outflows but, by eye alone, it is impossible to estimate site centrality reliably. This, surely, is the point of the exercise; to what extent are sites ‘central’ that don’t look so on simple grounds of geographical position and resources? However, for those models, which include the familiar Proximal Point Analysis (PPA) in which the links are non-directional (or for which,

more generally, inflow equals outflow at each site), site *rank* reduces to the simpler site *inflow*, our first guess, and can be read schematically from the Figures, as can hub rank.[5] Nonetheless, 'betweenness' remains more elusive.

### 6.2.1 Generating Centrality

What the studies that we have cited earlier do is take a network designated by archaeological data and then 'measure' the centrality of sites on that network. With static networks, there is little scope for understanding what features might have generated different kinds of centrality. It may be possible to say, for example, by analysing known connections, that a site is significant in the sense above; but how did that site come to have such connections in the first place? Rather than assume that network function follows from network structure, we should consider how structure is tied up with function. Network structure is emergent and dynamic. But how we can access this 'agentive' quality of a network?

In common with many other authors we assume not only that networks have functions, but that their structure will, in some sense, be approximately 'optimal' in fulfilling those functions. In particular, where regional 'exchange' networks are concerned, the likelihoods, costs and benefits of movement across physical space are important factors (e.g. see Barthélemy 2011) in characterizing optimal behaviour. We shall discuss several mechanisms for generating networks that encode some form of optimization. Given our understanding of the archaeological record we can decide which models give the most plausible outcomes. However, all models work with a very broad brush and, even if the overall pattern looks plausible, which particular sites achieve the highest centrality within a model can depend on details (e.g. typical journey length) about which we have only imprecise knowledge. For that reason, our preferred model ('ariadne', see later) has stochastic outcomes that we can interpret as plausible 'histories' of the system that can arise from the same initial conditions and which have to be interpreted statistically. We shall turn to this later.

We organize our models essentially according to the number of assumptions that we make, the simplest (null models) first. There is no doubt that exchange networks are directional, but sometimes it is a convenient fiction to drop directionality, since it simplifies model-making. When trying to identify centrality we separate mechanisms into those which generate non-directional networks and those which generate directional networks, since they possess different behaviour with regard to rank, although less so with regard to betweenness.

[5] Unfortunately, for such *non-directional* (or equal in- and out-strength) networks Katz ranking typically tracks site size for our networks. Even for our directional network models Katz ranking tends to follow site size and we shall not use it to discriminate between sites in the subsequent discussion.

## 6.3 NON-DIRECTIONAL NETWORKS

As null models, we first consider simple unweighted networks, dependent either on physical geography or on limited exchange.

### 6.3.1 Geographical Networks

The simplest assumption is that there is a typical distance *D*, determined by marine technology, beyond which single journeys become too difficult, almost whatever the nature of the exchange, but that distances shorter than this are regularly taken. Sites are linked if their separation is less than *D*. If *D* is shorter than the typical inter-site distance then it will be very difficult for an exchange network to form. On the other hand, if *D* is much larger than the inter-site distance we have almost a *complete* network, in which every site is connected to the majority of sites. This suggests an interesting picture, if we assume that *D* increases in time as a result of improved sailing technology. In that case we expect a strong large-scale exchange network to come to life once the technology is such that sea journeys can match inter-island separation.

This is a little simplistic. When considering the ease of travel between sites, we are really concerned with travel times, for which distance is not always a good proxy. In particular, we introduce a reasonable frictional coefficient for land travel in comparison to sea travel. Its main effect is to make southern Crete less accessible to northern Crete by land.[6] Even then, travel time can be directional, particularly for maritime journeys with winds and tides. Despite that, we anticipate that over the period of a year such behaviour tends to average out, and we keep our 'distances' non-directional.

We find that, for travel distances *D* of 100 km or less, there are four regional clusters, the Cyclades, Crete, the Peloponnese, and the Dodecanese. As we increase *D* to about 110 km the Cyclades connect to the Peloponnese, initially through Phylakopi. At about 120 km northern Crete connects to the Cyclades through Thera and the Peloponnese through Kos and Kalymnos (see Fig. 6.1). Continuing to increase *D* then enables the Dodecanese to connect to eastern Crete, via Rhodes. In the Early Bronze Age (EBA) these distances are too large for paddle/oar-based vessels to make more than occasional journeys and there is no thriving network on this Aegean-wide scale. Nonetheless, there is an established Cycladic network, for which inter-island distances of the order of 30 km are perfectly commensurate with distances of canoe travel (Broodbank 2000). However, in the Middle Bronze Age (MBA) the appearance of sail means that

[6] Our conclusions are largely indifferent to this value as long as it is somewhat larger than unity. To be explicit we take a frictional coefficient of 3.

distances of 100 km and more are possible and, unsurprisingly, a vigorous maritime network develops (and for this reason, the sites chosen are MBA sites).

*Rank* is purely geographical, the rank for distance scale *D* being essentially an ordering by the number of nearest neighbours to each site within a circle of radius *D*. High site density is correlated to high rank. This favours northern Crete and the Dodecanese, with Phylakopi prominent in the Cyclades. However, since there is strong regional grouping, even for small *D*, rank does not vary widely. Which sites are gateways is also a direct measure of geography, in particular for sites that form bridges between regions as *D* is increased and regions begin to connect. For the southern Aegean we see bridges between Phylakopi–Kea and Thera–Malia (with precedence, by distance alone over Thera–Knossos). Phylakopi and Malia have high betweenness.

### 6.3.2 Proximal Point Analysis (PPA)

While there is no doubt that geography informs network formation, ease of travel is only one factor in their composition. To adopt the very different viewpoint of Proximal Point Analysis (PPA), it may be that there is an optimal number of relationships between one site and its neighbours that can and need to be sustained properly, *independent* of site size and site separation. Most simply, we connect each site to its *k* nearest neighbours with outward links, for some small *k*. When the process has been completed, link direction is removed, to create an undirected final network. As a result, *rank* now becomes identical to site 'degree', provided we also give an equal weight to each link. Visual inspection is sufficient. This is how PPA was used by Broodbank (2000) in EBA networks for the Cyclades.

Although geography still defines neighbouring sites, distance is no longer the sole determining feature. By its nature, PPA tends to reproduce the strongly connected cores of the geographical network. In our Fig. 6.2 (for $k = 3$) these comprise the Cyclades, the Dodecanese, and Crete. As before, the regions where there are sites with high rank are those regions with high site density. However, with distance less important, there are striking differences in the way regions connect to each other. Already, for $k = 3$ we can circumnavigate the southern Aegean in a continuous loop, part of a tendency in PPA for connected sites to form chains. Gateways are relatively simple to identify, as happens when geographically isolated sites like Cesme bridge the Dodecanese and the Cyclades, unlike the case where distance dominates connections. For the sites in hand, it is necessary to take $k = 4$ before Crete is connected to the Cyclades (through Thera), However, if we were to increase the number of sites for the same *k* value, this connection would disappear. This means that how connections form depends both on *k* and on the sites we have deigned to include.[7] For

[7] Even for the simple geographic networks rank depends on the sites that are included. However, connectivity between regions is controlled by spatial separation and is less susceptible.

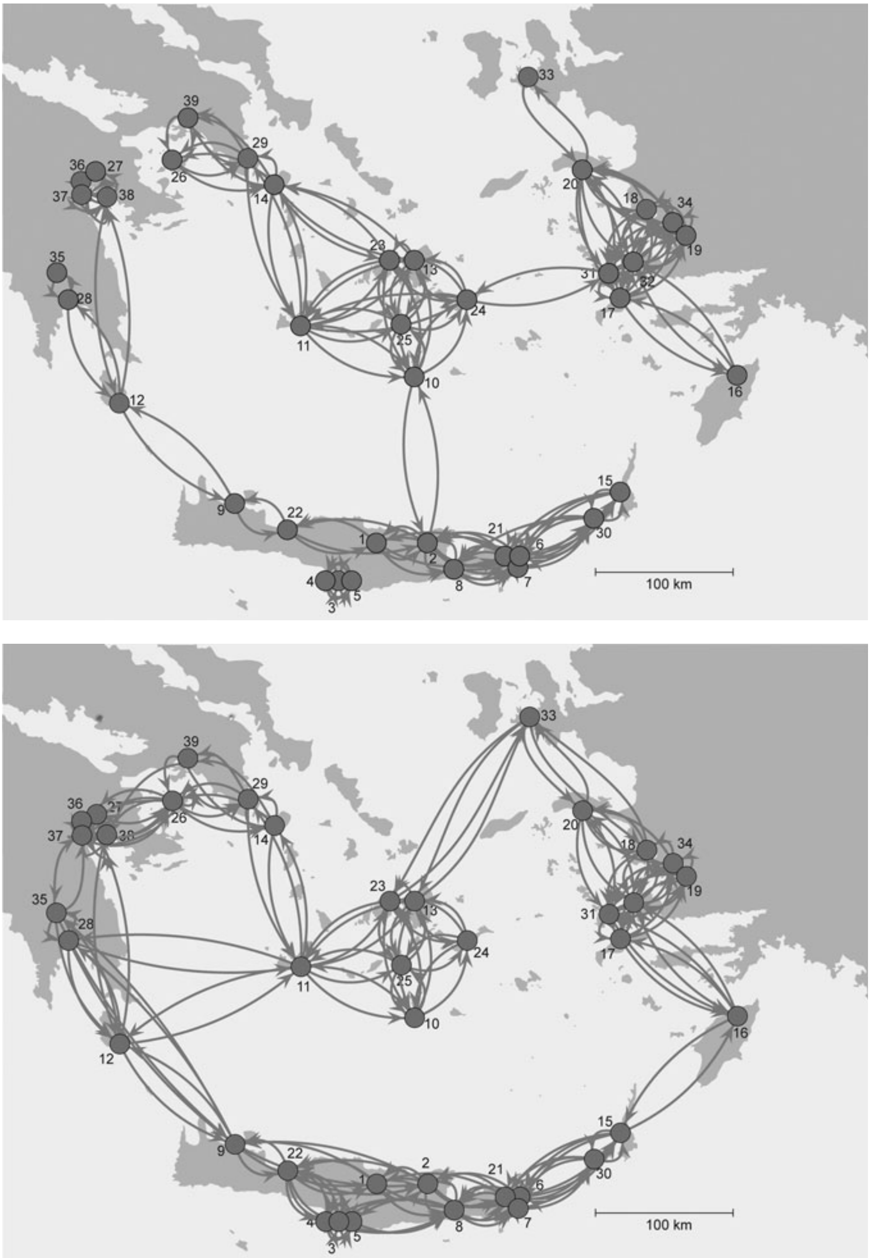


**Fig. 6.2.** Contrasting a simple geographical distance network ($D$ = *125km*) in the upper figure to PPA ($k$ = 3) with its emphasis on connection in the lower figure. Vertices are labelled by betweeness.

this reason, for the MBA Aegean there is sufficient ambiguity in the numbers and positions of sites for PPA not to be a helpful guide for defining centrality.

### 6.3.3 Simple gravity models

Returning to our earlier comments on 'forces', the 'attraction' of centres is often construed as a 'gravitational' pull. Thus, for example, Renfrew (1977: 87) brings up the notion of gravity when he shifts from discussing artefact availability by a diffusive 'push' to the role of central sites in introducing directionality into material distribution patterns. In fact, as we shall see, in several approaches to network dynamics gravitational concepts arise very naturally.

In the first instance the pattern of distance scales in simple unweighted geographical networks has a natural extension into 'gravity' networks with equally undirected but *weighted* links, in which exchange also depends on site size as well as inter-site difference; the larger the sites the greater the exchange, the larger the distance the smaller the exchange.[8] Following on from their work as planning tools from the 1960s onwards (e.g. see Jensen-Butler 1972), gravity models have been recognized as a useful tool in regional analysis in archaeology since the 1970s (Plog 1976; Johnson 1977; Renfrew 1977; Conolly and Lake 2006). They mitigate against the problem noted above that we might expect different results if we were to include further sites as good MBA candidates, either as a result of new finds or a desire to be more thorough, in that they aggregate local sites into collective 'gravitational centres of resources and population' and aggregate exchanges accordingly. This can be construed as one aspect of optimization in that, in reducing our need for detailed knowledge of local sites it minimizes the effects of some aspects of our ignorance. It is for this reason that we have only allocated one site per island, for small/medium islands.[9]

More relevant than site 'size' in the sense of resources (or carrying capacity) is site population which, when not requiring 'imported' resources to sustain the site, is a reflection of resource exploitation. For the moment we take one proportional to the other, although in our model to be discussed later we have

[8] The way in which exchange falls off with distance is controlled by $D$. For distances shorter than $D$ we assume that journeys are relatively easy to make, and for distances larger than $D$ they are difficult to make. The simple geographical distance model above takes this as a step function (unity for separations less than $D$, zero for separations greater than $D$). A literal 'gravity' model would take it to fall off inversely with distance. We take behaviour that lies between the two with a smooth transition from one to the other regime. Results are largely independent of the details of the transition.

[9] Mainland coastal sites or Cretan sites essentially behave as islands because of the difficulty of land travel.

carrying capacity as *input*, population as *output*. For brevity we shall call population/resource exploitation as ‘population’ alone, although we appreciate that the situation is more subtle. From this viewpoint, the simple geographical analysis earlier essentially corresponds to taking all sites in Table 6.1 as having the same population. This is unrealistic. In Table 6.1 we have classified a site’s size as ‘small’, ‘medium’, or ‘large’ on the basis of archaeological evidence. Even this crude division, in which the ratio of resources is 1:2:3, is sufficient to show the effects of differences in resource availability. If we take the populations proportional to carrying capacities, then *rank* is no longer simply geographic and has to take site size into account. As a result, small sites struggle to achieve high rank, with Cretan sites on the north coast now dominating the table, both with regard to rank and betweenness (with respect to the latter, Naxos, Miletus, and Thera have the highest betweenness after northern Crete). However, Thera has high *impact*.

If we use ‘geography’ as shorthand for the inter-site distances and site carrying capacities, and ‘technology’ as shorthand for the ability to travel (*D*), all the models above have essentially used only geography and technology, even if the outcomes are not simply geographic. With essentially no freedom of choice there is little surprise that they produce the obvious. To go beyond this requires a more sophisticated sense of agency than how far, how many, how big?

## 6.4 DIRECTIONAL NETWORKS

Hitherto, we have assumed undirected (reciprocal) links, which is not how exchange networks operate. Simple gravity models impose penalties on long, single journeys, while PPA imposes penalties on sustaining too many links. With this in mind we consider more generalized models which accommodate ‘gravity’ while being directed.

Let us return to the notion that networks are, in some sense, ‘optimal’. Usually, we think of this as an ‘active’ aspect of agency, so that the individuals/communities/polities make conscious, albeit imperfect choices, which optimize their exchanges in some ways. We shall turn to such optimization later. For the moment we consider a passive alternative to optimization that has nothing to do with community behaviour, but everything to do with our knowledge of it, in which we minimize the consequences of our ignorance (as we have already begun to do with our use of gravity model aggregations). Suppose, given our aggregated sites, we only know a few features of the network, such as the necessity for exchange (related to site size) and a fixed overall ‘cost’ of exchange. We can construct many networks compatible with these constraints. If we give these networks equal statistical likelihood, on the

grounds that to discriminate between them would assume more knowledge than we possess, we can ask what is the 'most likely' type of network to evolve, again in a statistical sense.[10]

We borrow the idea from contemporary modelling of urban traffic flows (Erlander and Stewart 1990; Ortuzar and Willumsen 1994), with potential parallels to historic and prehistoric exchange networks. The outcome of this optimization is a *gravity model* (Batty 2010) where we have traded network cost for travel distance *D*. We shall give no details here because *rank* is (almost) simply proportional to size, giving all sites essentially identical centrality in the sense of Renfrew (as is Katz ranking). This is not a useful way to proceed, but models like this have the important ingredient that, as with PPA, even remote sites have to couple to the network, whatever *D*.

### 6.4.1 Urban Retail Models: The Rihll and Wilson Model

Transport modelling networks are most simply taken as undirected since, in the absence of any prior information, it is sensible to take site inflows *equal* to site outflows. To introduce directionality we first consider a variant, which takes us *a* step beyond geography and technology, originally designed for urban planning (Wilson 1970, 1971; Wilson and Harris 1978). This has been adapted by Rihll and Wilson (Rihll and Wilson 1987, 1991) to an Iron Age archaeological system, that of mainland Greek city states, but we shall apply it here to our MBA sites. In this variant the site outflows are initially taken as proportional to site capacity (as for simple transport models) but the inflows are now *outputs* determined by the search for most likely networks, the networks characterized by a new attribute termed 'attractiveness'. In introducing this new feature we have broken the simple connection between rank and size. It is, of course, highly unlikely that we can do more than provide the simplest caricature of an evolving network with just a single new free parameter, as we now see.

The generic behaviour of the network as attractiveness changes is straightforward (Dearden and Wilson 2009, 2010). For low attractiveness we have many small competing sites. As attractiveness increases a handful of these sites show increasing inflows until a very few sites dominate the ranking tables so strongly that there is no ambiguity about defining them as hubs, drawing in all the 'trade' (outflow) of their weaker neighbours.[11] The rapidity of this change

[10] Technically, what we are doing is *maximizing* entropy, a statement about the information encoded of the system, subject to constraints.

[11] Remember that this model was devised, among other reasons, for the placement of shopping centres, needing to draw in their clientele, for which 'goods' above equates to 'money'. In this context we are seeing the replacement of local stores by a few retail centres.

of behaviour as the network changes from a collection of little sites to a few major hubs is stronger for large *D*, weakened as *D* is diminished, when there are more, but less dominant, hubs. For the relevant range of *D* from 80 km to 130 km for the southern Aegean the *rank* profiles vary smoothly with *D*. Each regional grouping contributes to the creation of central places. Larger *D* favours the Cyclades, smaller *D* favours Crete and the Peloponnese (see Fig. 6.3 for examples).

When there are many competing sites, as in Fig. 6.3a (in which site size is a measure of betweenness), northern Crete, Phylakopi, Kalymnos, Thera, and Asine have high betweenness and northern Crete, Thera, and Phylakopi have high rank. Since several small or medium-size sites have high rank, they have even higher impact (transactions per head—Renfrew's centrality). Joining Thera and Asine are Ios and Kalymnos. As we move to fewer competing sites (larger 'attractiveness'), as in Fig. 6.3b, highly ranked sites become regional hubs. Depending on *D* the most likely hubs are one from each pair of Phylakopi/Ios, Gournia/Petras, Myndus/Kalymnos, and Asine/Lerna. For such directional networks betweenness is strongly correlated to rank although hubs can be linked by bridges such as Phylakopi–Cesme that we have seen before. This is for the same reason, that PPA and constrained entropy models enforce some exchange over single journeys of large distances that less prescriptive models would expect to be achieved with stopovers. However, important as they may seem to be, in practice, bridge ends can have low betweenness by our definitions (sites in Fig. 6.3 are displayed by betweenness). We see that, by virtue of its other links, it is Phylakopi that has the high betweenness (and rank) and not Cesme and other outlying bridge ends.

How do these outcomes match our expectations of maritime networks? Superficially, this picture of hub sites, carving up the network into competing zones of influence, battling it out with each other for the outflow of the remaining sites, is reminiscent of the XTENT model in the patterns it produces. However, it differs dramatically from XTENT in that it describes an implosion of the components of 'trade' to the hubs from other sites, rather than an outward diffusion. In the language of maritime exchange, vessels from neighbouring sites leave with goods, return empty (see footnote 11). This is more like tribute than trade and not how we understand maritime networks to behave. For that reason we shall not consider the model further, despite the detail with which we have examined it.

However, before passing on, it has brought an issue to the fore: the relationship between site size (carrying capacity) and site weight (population) which, except for the explicit gravity model introduced initially, has played no direct role to date. Insofar as they have been relevant, site populations have been part of the model *input*, to be chosen more or less at will. This is not surprising, given the origins of entropy-maximizing models in transport and retail models, for which flow is all and the notion of residential populations is

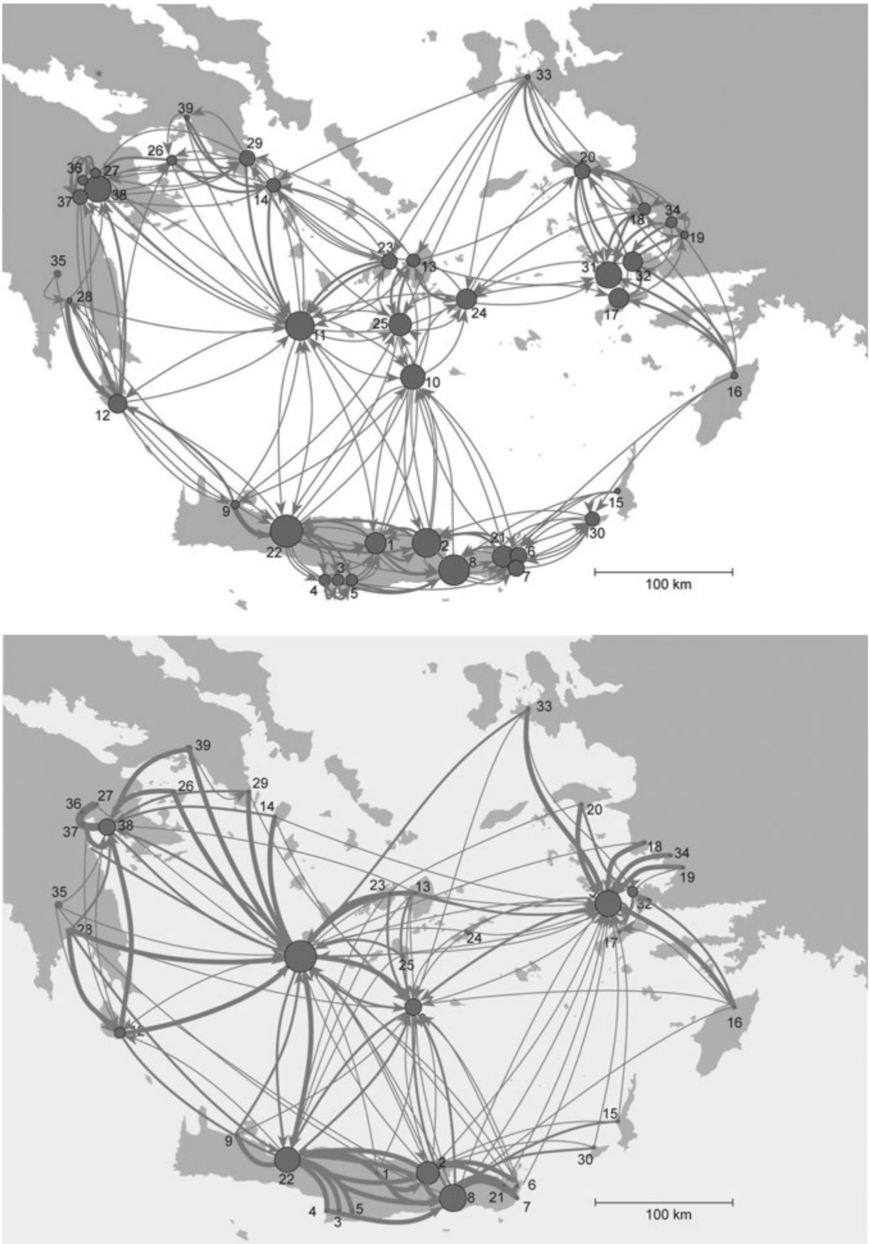


Fig. 6.3 a–b. Two networks in the Rihll and Wilson model. Fig. 6.3a has lower attractiveness than Figure 6.3b. Vertices are labelled by betweenness.

meaningless or unhelpful. The historical record shows that we should not correlate population to resource availability too closely (i.e. assume constant population density) since we see sites with limited local resources able to sustain greater populations because of their exchange with the rest of the network. In fact, a necessary condition for a model to be realistic is that it should give rise to varying population densities. For this we need further ingredients in our models.

### 6.4.2 Cost-Benefit Analysis: *Ariadne*

We shall now examine optimization in the context of 'efficient' networks. By 'efficient' networks we mean *actively* 'optimal' networks, seeking to maximize the benefits of exchange, while seeking to minimize their 'costs'. In practice our networks are 'almost optimal' in that it is difficult to find the 'best' choice and it is sufficient to choose between several comparably good options. This stochastic element distinguishes this model from the deterministic models discussed previously. The model we shall describe here, named '*ariadne*', has been given in some detail in papers and articles published elsewhere (Evans et al. 2009, 2012; Knappett et al. 2008, 2011; Rivers et al. in press). We refer the reader to these papers for a fuller explanation.

The way to quantify 'almost optimal' is to reinterpret 'optimization' as the 'minimization' of a quantity we term the 'social potential' or 'utility function'.[12] We can think of this potential as describing a 'landscape' whose coordinates are site populations and the strength of the links between them. 'Optimization' then corresponds to looking for the lowest point in this landscape (and identifying the network corresponding to this minimum). This landscape has very high dimension and there are many points (networks) competing to be the lowest. To take only the lowest of the minima is unnecessarily restrictive and suggests a more stochastic approach, in which we take comparable minima into account in a statistical way so that, for example, we might say that (on re-running 'history' several times) Phylakopi is a dominant hub three times out of five, Ios two.

The social potential in *ariadne* must contain at least two terms, one for the benefits of exchange and one for the costs of sustaining the network. As for the former, we take the benefit/utility attached to an exchange link to be conventionally 'gravitational', proportional to the product of the 'centre-of-mass' 'populations', with an inter-site 'potential' falling off strongly at distance $D$, using the ease-of-travel interpolating function discussed earlier (footnote 8).

[12] Although we did not introduce it at the time, for the Rhill and Wilson model this potential is the negative of the entropy.

We stress that here the populations will be *outputs* of the optimization. The mutual homophily of the gravity input means that large sites benefit hugely from interacting with large sites. Empirically this seems a necessary condition for the generation of the wide range of populations seen in the record. Further, as we have already observed, by adopting gravity inputs, we can approximately aggregate local resources into larger (e.g. island-wide) sites without needing local knowledge. As for costs, two obvious candidates are the cost of sustaining the total population or the cost of sustaining total exchange ('trade') and we assume that the total cost will be a combination of these.

While these terms may be necessary, it is straightforward to show that just these costs and benefits alone are still not sufficient to give the desired range of population densities. Specifically, provided the costs are not too large with respect to benefits, populations are almost proportional to site size, with not the wide variation we are looking for, despite the latter's gravitational nature. Also, there are very few of the weak links necessary to stabilize the network against change. In fact, as we now increase the costs an increasing number of sites collapse, with effectively zero weights/populations. Although there are some differences in how this comes about, according to how costs are allocated, the surviving sites in the network still maintain weights/populations remarkably proportional to size.[13]

However, just as the urban retail model that we have discussed above for locating shopping malls breaks down if consumers also have their own vegetable gardens, livestock, etc., models for realistic trading networks do need to take the benefits of local resources into account. Their contribution to the social potential is a benefit, a cushion against population costs (although it can incur a cost if the resources are over-exploited). This suggests that the simplest social potential required on general grounds should include all four terms (benefits from exchange and local resources, costs for sustaining trade and population). The aim is to find the configuration of the network that makes the social potential as *small* as possible. This takes us further beyond geography and technology, in having to estimate the relative benefits of local resources to those of exchange, the *total* population, and the relative costs of sustaining the network. In practice, we can (almost) compensate for changes in one through changes in the other two, giving an effective model that is effectively only *two* new steps. The output is now not just outflows but also site populations. The 'social landscape' through which we hunt has, again, many minima (valley bottoms) that correspond to networks that are comparably optimal.

[13] For example, increasing the costs of sustaining the network gives rise to chains of strong links rather as in PPA.

### 6.4.3 *Ariadne*: Centrality

As we anticipated, not only do we break away from the proportionality between site size and population for functioning sites, but we have weak links that betoken stability. However, even with only 'two' new parameters it might be thought that there is too much freedom for the model to be useful given the relatively fragmented record. This is not the case. Just as we saw, for the Rihll and Wilson model, the need to steer away from instability by restricting attractiveness, *ariadne* can equally show instability, such as when the costs of sustaining the network become too high.[14] This is an almost inevitable consequence of the model's built-in homophilic tendencies, in which the non-linear benefits of large sites exchanging with large sites and thereby making large sites larger, is in precarious balance with the non-linear costs of over-exploitation of local resources. Avoiding this behaviour restricts us to a limited range of parameters.

Our approach has been to begin with a choice of parameters that give a plausible network. As we have observed, if we ignore local resources we have networks with population proportional to site size and large sites need to exchange so strongly with other large sites to compensate for inadequate local resources that the system breaks down. On the other hand, once we invoke local resources, if the benefits of exchange are too small, then islands try to become largely self-sufficient, but again making individual island collapse frequent. This is commensurate with the observation by Broodbank et al. (2005: 95):

> For the southern Aegean islands in the late Second and Third Palace periods, an age of intensifying trans-Mediterranean linkage and expanding political units, there may often have been precariously little middle ground to hold between the two poles of (i) high profile connectivity, wealth and population, or (ii) an obscurity and relative poverty in terms of population and access to wealth that did not carry with it even the compensation of safety from external groups.

Although the freedom in the model is not so large as to enable us to get any behaviour we wish, there still is considerably more choice in the way that central places can be generated than in our earlier models. Nonetheless, despite the uncertainty introduced by our statistical analysis, there are a set of orderly patterns for the creation of centrality according to the scenario in mind. We have already mentioned the case in which, all other things being equal, increasing the costs of sustaining the network leads to instability as the sites concentrate on fewer and stronger links (Knappett et al. 2011). We

[14] We have invoked this (Knappett et al. 2011) as one of the plausible reasons for the collapse of Minoan influence some time after the eruption of Thera.

consider a different situation, far removed from instabilities, that arises as the benefit of exchange increases, all other things being equal.

By trial and error we find that some types of network are impossible to achieve, or extremely rare. Those networks that arise easily have a dominant Crete, connected to the mainland by a western string through Chania and Kastri and to a weaker Cyclades primarily through Thera and Phylakopi. There is a strong Dodecanese that is only intermittently connected to Crete directly through Rhodes, and not particularly strongly connected to the Cyclades through Naxos.

This is more or less as we might have expected, from simple geography alone. The interest lies in the detail. As we said, our model is not strictly deterministic in that we choose statistically between comparably efficient networks. This is to the good, given the inevitable fuzziness in attempting to quantify the 'best'. Typically northern Crete connects to the Cyclades through Thera, with western Crete and Kastri connecting to Phylakopi. We give an exemplary network in Fig. 6.4 in which the site sizes correspond to 'population' (Fig. 6.4a), rank or 'busyness' (Fig.6.4b), and betweenness (Fig.6.4c). We see that there is a strong, but by no means exact, correlation between them. We should pay more attention to the general pattern than to the details, since different runs of the programme give different fine structure (see Fig. 6.5).

In this particular network Knossos plays no major role. However, on re-running the simulation several times *from the same parameter values* we find that, for a substantial fraction of the time (about 25 per cent), there is a dominant exchange between Thera and Knossos or Malia. In Fig. 6.5 we show one network in which the link between Knossos and Thera is overwhelming, with Thera an unambiguous gateway to the Cyclades. Such a network is not to be expected on simple ideas of geographic space alone. Its behaviour is equally optimal as that of Fig. 6.4, but the latter is more likely to have occurred. The former is more susceptible to contingence, although we do not know what the contingencies might be. We stress that we should not put too much emphasis on individual networks. Nonetheless, we find it striking that such behaviour arises in our model without too much difficulty.

## 6.5 SUMMARY

In this article we have shown how one might identify important archaeological sites by means of their 'centrality'. Colloquially we know what this means; sites with substantial resources in proximity, or manageable contact, to several or many other sites, preferably also important, with which exchange is conducted. An important question is whether such sites can be simply estimated

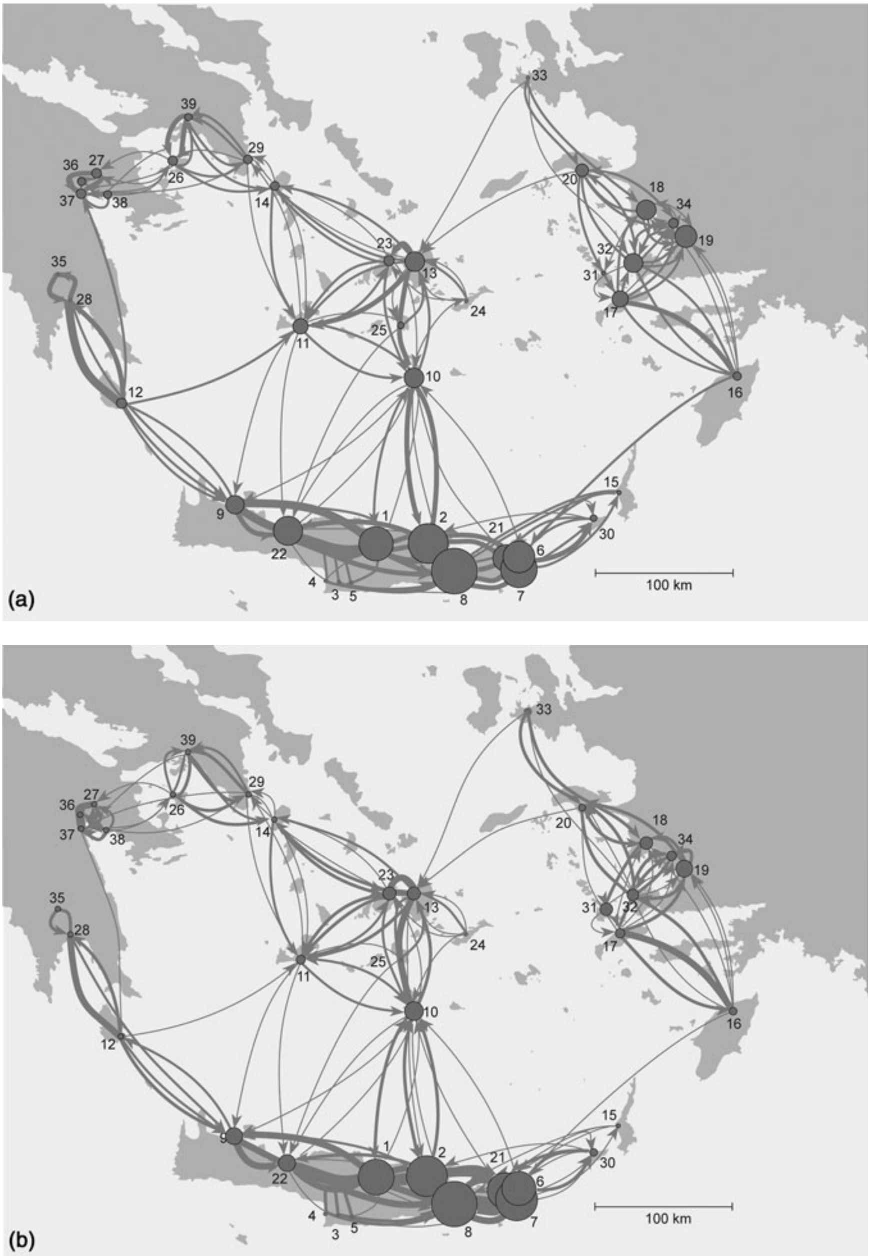


**Fig. 6.4.** Exemplary networks from *ariadne*, showing site rankings with respect to population (Fig. 6.4a), business (Fig. 6.4b) and betweeness (Fig. 6.4c) respectively. We see the strong correlation between them. Population is an output in *ariadne*. Site resources, or carrying capacities are inputs, listed in Table 6.1.

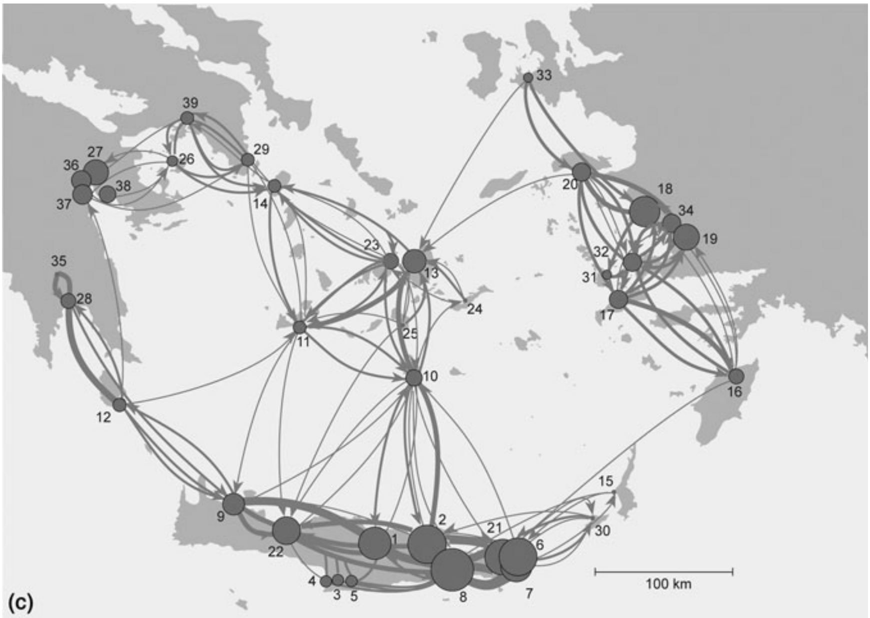


**Fig. 6.4.** Continued

by the spatial geography of the network and some knowledge of site size, without having to be more sophisticated.

We have argued that we need to do more than look at the map, the map in question being that for MBA maritime networks of the southern Aegean, about which we have written at some length elsewhere, but not in the context of centrality. Central sites include both those that are the most active in the exchange process and those that mediate the network flows. To this end we have introduced two kinds of centrality. The first is Renfrew's notion of a 'central place', understood as eigenvector centrality, which we have termed *rank*. For such networks a passable proxy for *rank* is the busyness of harbours as a measure of the flow of goods, people, and ideas between them. Our second measure of centrality is a version of betweenness centrality, termed *betweenness,* from which we can infer 'gateway' sites.

Empirically (and sometimes analytically), if the links between sites are not directional, site *rank* is the effective site degree, assuming that links are essentially unweighted (strong links counted, weak links not). Models of this type include simple geographic and gravitational models and PPA. With effectively no free parameters beyond estimates of site-carrying capacities

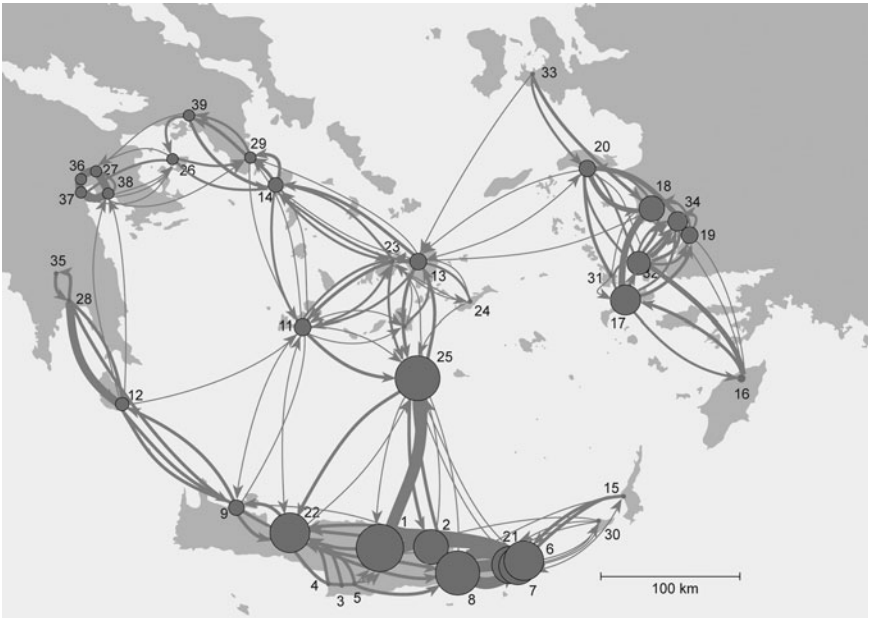


**Fig. 6.5.** A network in which the link between Knossos and Thera is very strong. The model parameters are identical to those used in Figs. 6.4a–c. Sites are labelled by their betweeness, but there is significant correlation between all measures of centrality.

and ease of travel by sailing vessel, they paint with a broad brush, in this case the wrong picture.

There is more to agency than ability to travel and a desire to maintain links. We have assumed that networks arise that, in some sense, are optimal. We have considered both passive and active optimization. The former corresponds to looking for the most likely type of network compatible with our limited knowledge of the system (entropy maximization). Adopted from transport models and models for contemporary urban planning, the simplest application of these ideas is in the network modelling by Rihll and Wilson for Iron Age Greek city states, which introduces a variable construed as site 'attractiveness'. As applied to the MBA it provides for more interesting scenarios in which dominant hubs arise, typically one in each of the four geographic regions of the southern Aegean. It provides a good counter-example to our null models with their emphasis on geography, and leads to outcomes that are not predictable from map reading. However, this is still a highly constrained model which, in the directedness of its links, is at variance with the record, a reflection of its origins for describing the transition from shopping streets to shopping malls.

For the reasons above we abandon it for our most substantial model, named *ariadne,* which is also optimal, but adopts a cost-benefit approach, looking for networks in which the benefits of exchange and local resources exceed the costs of sustaining exchange and the local populations. This is less prescriptive but, even then, has relatively few parameters. We have shown the role that our different understandings of centrality play here, particularly in the connection of northern Crete to the Cyclades and beyond. This, while being by no means predictive, in particular because of our stochastic analysis, with the emphasis it gives to Cretan sites and their connection to the Cyclades and the mainland via a Western link, is not in obvious disagreement with our expectations. For example, it is relatively easy to find networks in which Knossos and Akrotiri have high betweenness and are highly ranked. Other sites that play an important role include Phylakopi and Kalymnos (for example) and we need to see to what extent this is reflected in the archaeological record.

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# 7

# The Evolution of Prestige Good Systems: an Application of Network Analysis to the Transformation of Communication Systems and their Media

*Koji Mizoguchi*

## 7.1 INTRODUCTION

This paper proposes a two-stage evolutionary[1] model of 'prestige good systems' (cf. Friedman and Rowlands 1977: 224–32). The model is based upon the understanding that prestige goods are *symbolically generalized communication media* (cf. Luhmann 1994: 161–3) that mediate (and enable) the reproduction of communication systems spread across a spatio-temporal domain of more than a certain scale. The paper contends that the reproduction of such communication systems depends both on the hierarchization of their structure, and an increase in symbolic sophistication of media as their spatio-temporal scale increases. The argument will be supported by two case studies from pre- and proto-historic Japan: the Yayoi period (the first agrarian period of the archipelago, between *c.*600 BC and AD 250/275), and the Kofun period (the period characterized by the construction of numerous keyhole tumuli, between *c.* AD 250/275 and 600). We will apply several network analysis methods to these case studies.

If we define the minimum and basic unit of society to be *communication*, we need to situate the issues concerning how society works and changes within a framework of the theory of communication.[2]

[1] By 'evolutionary' I mean that a certain range of media for communication are generated through communicative acts, selected by differential rates of fitness for their (i.e. communicative acts') continuation, and stabilized as the media of the communicative acts.

[2] The following description on the theory of communication and the way in which it is applied throughout the paper draw upon Luhmann's work (1994).

Communication is a type of self-referential system that maintains itself by reproducing the boundary between itself and its environment. The boundary is meaningfully defined by identifying relevant parameters for the continuation of communication. This identification draws upon a set of expectations concerning the material/immaterial setting of a communicative act, the category and/or position of those who utter/act in the communication, the history of the communication, and so on. In other words, those who are involved in a communication need to/are led to expect what the others will utter, how the others will act, and how they are expected by the others to act/utter in the typical material/immaterial setting in which the communication takes place.

As the scale of the society in which communication takes place increases, the reproduction of individual communication systems across time and space becomes increasingly difficult, because the spatio-temporal gaps that punctuate communication concerning a certain topic become wider, and because the membership of those who are involved in such a communication becomes increasingly varied and unstable. It means that as the scale of society increases, the reproduction of communication systems becomes increasingly difficult, and that in order for the communication systems to be reproduced despite this increasing difficulty, they need to be mediated by *new* mechanisms that help the communication systems to reinitiate and continue after a certain spatio-temporal gap.

One typical mechanism is the creation of *symbolically generalized communication media* that are associated with the reproduction of certain communication systems. Their presence guides people to make choices and utter/act in a certain way by activating a certain set of memories and expectations which are internalized through the recursive enactment of certain acts conducted by using the media, often in a formalized manner. *Prestige goods* can be characterized as such media which facilitate internally hierarchized communication systems to be reproduced across a certain spatio-temporal domain. By *internally hierarchized*, I mean that the communication draws upon a set of *hierarchical expectations*: the utterances/acts by those who possess a prestige good are met with obedient utterances/acts in a certain manner. Such hierarchization reduces the complexity generated by the involvement of a large number of individuals that varies according to the occasion, and hence reduces the risk of the communication coming to a halt or collapsing. In other words, prestige goods generate the *authoritative understanding* of the way society and the world works; they direct individuals to expect and judge how they ought to communicate with one another in a certain way in a certain setting.

How, then, do such items come to function as unique media facilitating the reproduction of internally hierarchized communication systems? Purely theoretical inferences like the above are useful in setting up operational models with which to decide what to examine and how, but do not take us much further. Therefore, in the paragraphs that follow, I wish to take an inductive

approach. This chapter will examine the events and processes that occurred around the beginning of the so-called "Kofun" period (*c.* the mid-3rd century AD) and in the late Middle Yayoi period (*c.* the late 1st century BC) as fairly typical cases of the sudden emergence of a large-scale, internally hierarchized, communicative domain, and will investigate and compare the conditions surrounding these episodes.

In order to reconstruct the conditions, some network analysis methods, namely the analyses of network centrality, will be applied. Network centrality analyses draw upon the simple premise that those entities that directly and indirectly involve and mediate communications between more entities than the others constituting a given network acquire more *influence* over the others, and hence acquire a higher potential for achieving an authoritative position (e.g. Hanneman and Riddle 2005: ch. 10). By calculating various types of the connectedness, or 'centrality', of each of the entities, called 'nodes', the entities are ranked hierarchically in terms of their potential influence and authority in the network (Hanneman and Riddle 2005: ch. 10).

## 7.2 THE BEGINNING OF THE KOFUN PERIOD

We will start by examining the beginning of the Kofun period.[3] The reason for the reversed temporal order will become apparent in due course.

The beginning of the Japanese 'Kofun' (Ko = ancient/old; Fun = burial mound/tumulus) period is, as the name suggests, commonly defined by the emergence and widespread construction/use of the keyhole-shaped tumulus (e.g. Kondo 1983). The construction of the earliest examples of the keyhole-shaped tumulus, the largest of which, Hashihaka (Fig. 7.1), is approximately 280 metres long, no doubt required a vast labour force. The deceased buried in them were deposited with a homogeneous set of grave goods, including bronze mirrors, bronze and iron tools and weapons and, slightly later, included characteristic jasper/green tuff products. The set, the earliest form of the keyhole-shaped mound, allied features such as the slate stone-built pit mortuary chamber, and the typical set of grave goods will be lumped together as a whole and called the Initial Kofun package (IKP) hereafter in this chapter (Fig. 7.2). The largest examples were built in the present-day Nara basin, the region later to become the seat of the successive capitals of the Japanese ancient state, established in the late 7th century AD (Fig. 7.3). It appears that many of the mortuary items constituting

[3] The following argument about the beginning of the Kofun period and the mechanism of the emergence of a large-scale, loosely hierarchized inter-polity alliance draws upon Mizoguchi (2009), although new arguments have been added and the content of the argument made more solid and detailed.


**Fig. 7.1.** The Hashihaka tumulus (from Shiraishi 1999 (original from Kunaicho Shoryo-bu ryobo-ka 1999), with modification).

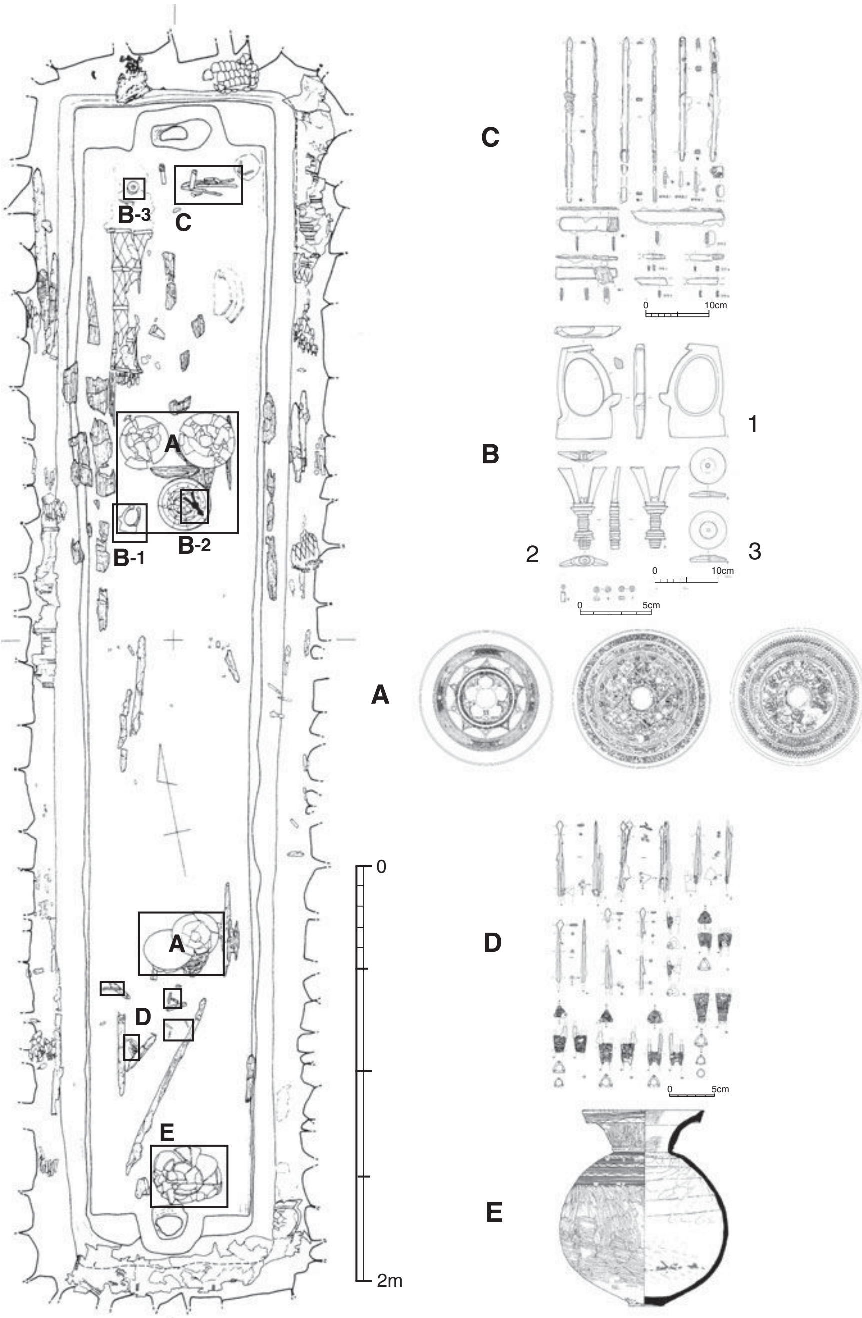


**Fig. 7.2.** The contents of the Initial Kofun package (the 'IKP'): the cist and the artefacts from the Yukinoyma tumulus. A: Bronze mirrors (including both imported and locally produced ones), B: Stone ritual implements (1: armlet, 2: item of unknown function, 3: spindle whirl-shaped implement), C: farming and wood working implements, D: iron fishing implement (harpoon), E: Flared-necked pottery (after Fukunaga and Sugii 1996, with additions).

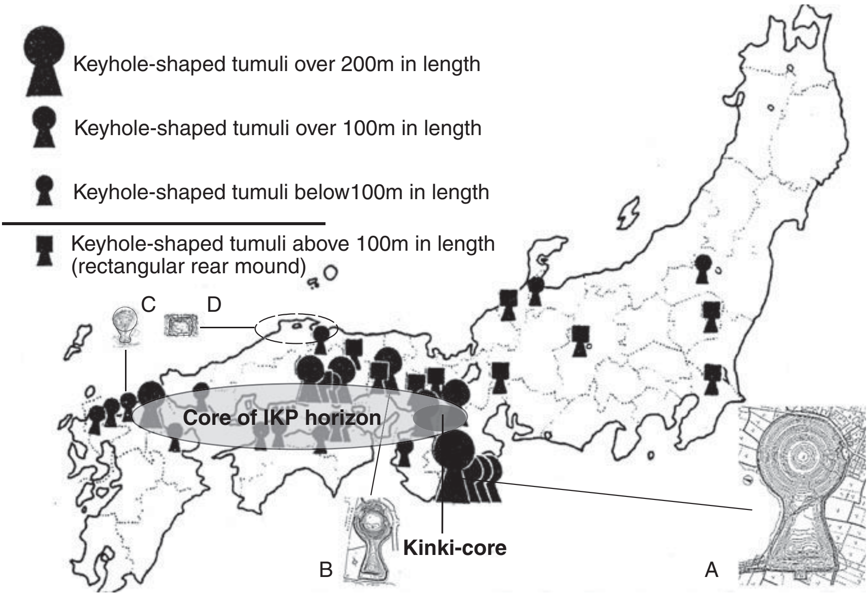


**Fig. 7.3.** Distribution and size differences of the earliest keyhole-shaped tumuli (source: Hirose 2003 with modifications): (A) Hashihaka (Yamato (G) in Fig. 7.4); (B) Yoro-hisagozuka (Harima: in between Kibi (D) and Kinki-core (G)); (C) Haraguchi (Tsukushi (B)); and (D) Onari (Izumo (C)). *The core of the IKP horizon and the location of the Kinki-core are indicated.

the IKP were distributed from the polity occupying the present-day Nara basin and Osaka plain of the Kinki region (hereafter referred as the 'Kinki-core' region) to the other regions comprising the IKP horizon. Interestingly, it appears that elements of the mortuary traditions and allied items developed in those regions, in what were later to become prominent members of the IKP-centred, hierarchized alliance in particular, were deliberately emulated and put together by the elite of the Kinki-core to create the IKP (Hojo 2000: 87–90, Terasawa 2000: 264–7). These facts suggest that the beginning of the Kofun period marked the emergence of a centralized and hierarchical alliance of polities reflected by the IKP horizon, the core of which extended along the Inland Sea corridor (Fig. 7.3).

What led to the formation of the Kinki-core-centred, hierarchical alliance has long been debated. There is no trace of militaristic conquest by Kinki-core (Matsugi 1998: 186–9), although some scholars argue that tension arose between Kinki-core and the northern Kyushu region from competition over access to overseas resources such as Chinese mirrors and Korean iron raw material (e.g. Tsude 1998). Nor is there any evidence during the preceding Late Yayoi (Yayoi V) period of monopolization by Kinki-core of the exploitation of or access to critical resources, either symbolic (bronze mirrors, for

example) or functional (iron raw material, for example). In fact, the northern Kyushu region (the ancient province of Tsukushi: see p. 158 and Fig. 7.4) had much better access to Chinese and Korean prestige items, and to the iron raw material that was believed to have been acquired in the southern Korean peninsula (Murakami 1998: 97–101). The northern Kyushu region was the clear centre in the distribution of Chinese bronze mirrors (Okamura 1999) and iron artefacts throughout the Yayoi period. What is more, the floodplains suitable for rice paddy-field farming in the regions over which the IKP were spread are small and scattered, and the Wittfogelian thesis arguing that centralized hierarchy emerged through the necessary centralized control of irrigation systems cannot stand. The only viable existing theses for the explanation of the phenomenon regarding the above observations, are: (1) Kinki-core enjoyed a high carrying capacity because of its large and stable floodplains that were suitable to paddy-field rice farming, and extended its politico-cultural influence across adjacent regions and beyond (cf. Kondo 1983: 128–30); and (2) the Nara basin of Kinki-core occupied the nodal position between western and eastern Japan, that naturally led to the formation of the Nara-centred hierarchical alliance (Kondo 1983: 132; Matsugi 1998: 185).

Larger productivity and carrying capacity would have given the region an advantage; these conditions would have enabled the communities of Kinki-core to outdo the others in competitive gift offerings/exchange (Friedman and Rowlands 1977: 206–24). However, such an advantage would have been enjoyed only in the relationship with the regions with which Kinki-core had direct and constant contacts. Besides, many regions, later to be incorporated into the IKP horizon, developed their unique ritual devices during the late Yayoi V period, and in fact broke away from the Kinki-centred bronze bell ritual horizon during the Yayoi V (Matsugi 1998: 178–82). These observations effectively disprove the first thesis, and render the second thesis the only viable hypothesis.

The second thesis has a significant characteristic. It does not try to find the advantage of Kinki-core in its attributes. It rather emphasizes its *locational advantage*; the advantage of the region was generated, rather than acquired or attained, from the relations it naturally came to have with other regions because of its location. This resonates well with the premises of social network analysis mentioned above and is worth further investigation.

If we define the beginning of the Kofun period as the beginning of the spread and acceptance of the IKP, the archaeological phase immediately preceding it,[4]

[4] Preceding the spread of the IKP; i.e. during the Yayoi VI/Shonai phase, prototypes of the keyhole tumulus, including the type with the round rear mound and that with the square rear mound, emerged and were distributed fairly widely, although sparsely. Some symbolic items, such as a certain type of bronze arrowhead that was deposited certain tombs, are argued to have been distributed by an emerging powerful group or groups of the Kinki-core region (e.g. Ikefuchi 2000). However, the overall situation points to the fact that the polities were competing over

the late Yayoi V and the early Yayoi VI (also called the 'Shonai' phase, named after the eponymous site of the characteristic pottery assemblage), saw the emergence of a number of horizons marked by the use of stylistically distinct pottery assemblages and the development of distinct ritual devices, including the custom of using and depositing bronze ritual implements and that of burying the elite and their close kin in distinctly shaped tumuli (Fig. 7.4). Many of them were to become cores of IKP distribution, and had been cores of the distribution of settlements in the Yayoi V. Therefore, these horizons, namely (B) Tsukushi, (C) Izumo, (D) Kibi, (E) Taniwa, (F) Awa-Sanuki, (G) Kawachi-Yamato (Kinki-core), (H) Koshi, (I) Owari, (J) Azuma (the East), after their ancient provincial names, are treated as the nodes in the following analysis. The Asian mainland, including the contemporary Chinese and Korean polities from which various utilitarian and prestige goods were imported, is heuristically treated as a single node (Fig. 7.4).

Let us focus on the situation in the late Yayoi V period (*c.* late 1st~2nd century AD). The interactions between the nodes in this era, reconstructed from the stylistic affinity and difference between the indigenous pots of the nodes and their exchange, were basically confined to adjacent nodes, although the flow of Chinese and Korean imports from one node to the next starting from Tsukushi appears to have steadily increased during the period. It is exceptional that Kinki-core appears to have had direct contacts with Tsukushi, reflected by some Kinki-core style pots excavated from the Hie site, one of the central place-type settlements of Tsukushi (Fukuoka Municipal Board of Education 1996). An edge may therefore be drawn between the Kinki-core and Tsukushi nodes (G and B in Fig. 7.4 respectively). Otherwise, edges are only drawn between adjacent nodes in this period (Fig. 7.5).

Let us now measure various types of *centrality* of individual nodes (cf. Borgatti et al. 2002: the following calculations were carried out with UCINET Ver. 6.239) (Tables 7.1–7.6). *Degree centrality measurement* (Table 7.1) shows that Kinki-core had the largest number of edges out of it, as Tsukushi, Izumo, and Kibi with four edges each.

The *Bonacich power centrality measurement* (Table 7.2), which, in measuring the centrality of a given node, takes into account the connectedness of the nodes to which it is directly linked,[5] shows that Izumo was best connected in the network, followed by Kibi and Kinki-core.

access to various sources of utilitarian and prestige goods in and outside the archipelago (Mizoguchi 2000; Tsujita 2007). Having said that, the process towards the formation of the Kinki-core-centred hierarchical alliance was set in motion sometime during this phase. Therefore, in this chapter, the Yayoi VI/Shonai phase is heuristically treated as the beginning of the Kofun period.

[5] The following explanations concerning the different centrality measurements are based upon the work of Hanneman and Riddle (2005).

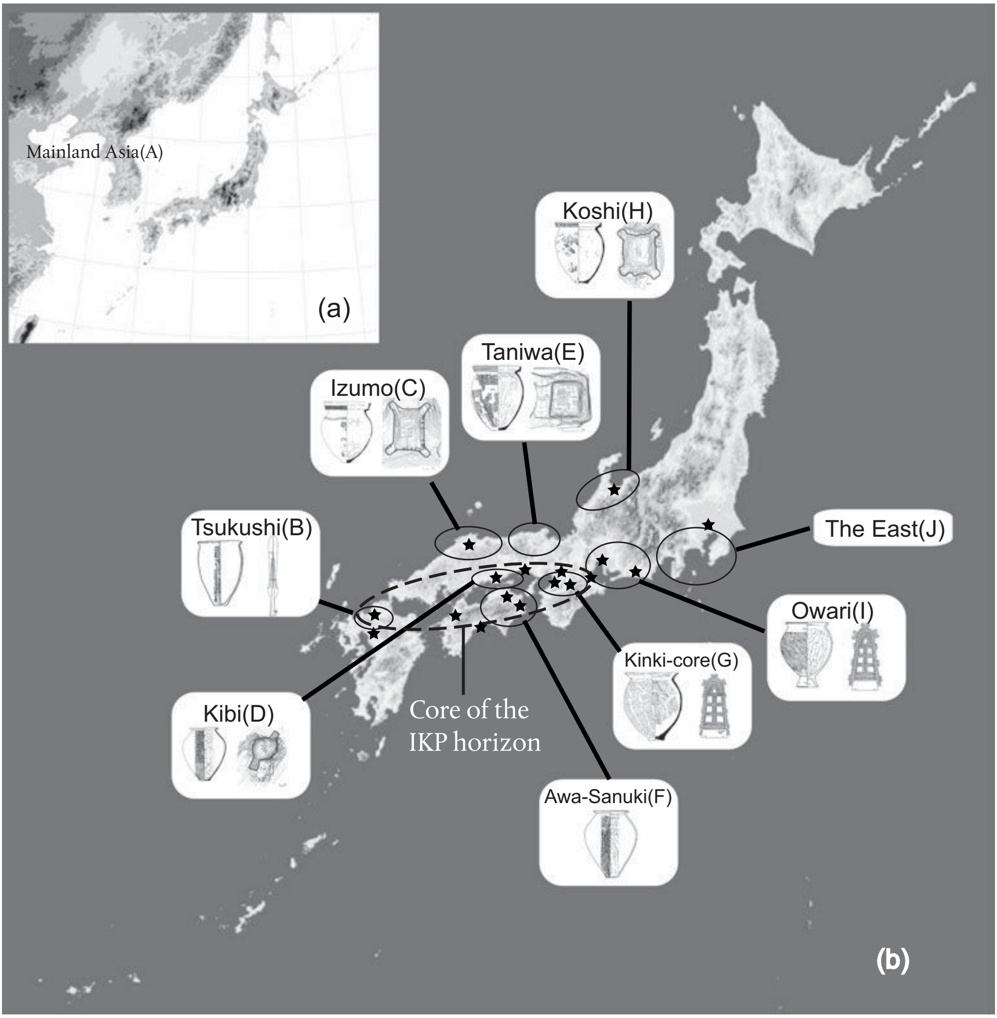


**Fig. 7.4.** The location of Japanese archipelago in East Asia (a) and ancient provinces as 'nodes' relevant to the investigation (b). Boxes show the characteristic mortuary mound forms/ritual items and pots of the respective regions. Stars indicate major floodplains in and around the core of the IKP horizon (see relevant descriptions). (From Mizoguchi 2009)

The *closeness centrality measurement* (Table 7.3), which shows the proximity of a node to every other node in the network in terms of the number of edges which have to be crossed to reach from the node to all the other nodes, produces a picture which coincides well with what the degree centrality measurement showed: Kinki-core is again at the top, followed by Tsukushi, Kibi, Izumo, Taniwa, and Koshi.

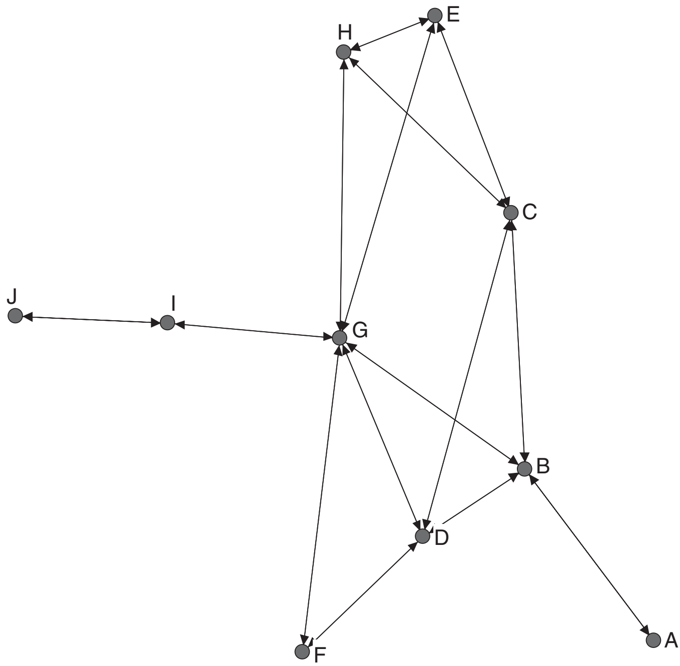


**Fig. 7.5.** The network of the late Yayoi V period (Regend A~J: see Fig. 7.4 and relevant description).

**Table 7.1.** Degree centrality

| Rank | Node | Degree |
|---|---|---|
| 1 | Kinki-core | 6.000 |
| 2 | Izumo | 4.000 |
| 2 | Kibi | 4.000 |
| 2 | Tsukushi | 4.000 |
| 5 | Koshi | 3.000 |
| 5 | Taniwa | 3.000 |
| 7 | Owari | 2.000 |
| 7 | Sanuki-Awa | 2.000 |
| 9 | East | 1.000 |
| 9 | Mainland Asia | 1.000 |

**Table 7.2.** Bonacich power centrality

| Rank | Node | Power |
|---|---|---|
| 1 | Izumo | 55.122 |
| 2 | Kibi | 51.777 |
| 3 | Kinki-core | 51.359 |
| 4 | Taniwa | 46.481 |
| 5 | Koshi | 46.481 |
| 6 | Tsukushi | 45.505 |
| 7 | Sanuki-Awa | 31.568 |
| 8 | Mainland Asia | 12.753 |
| 9 | Owari | 0.906 |
| 10 | East | −9.547 |

**Table 7.3.** Closeness centrality

| Rank | Node | Closeness |
|---|---|---|
| 1 | Kinki-core | 12.000 |
| 2 | Tsukushi | 15.000 |
| 2 | Kibi | 15.000 |
| 4 | Izumo | 17.000 |
| 4 | Taniwa | 17.000 |
| 4 | Koshi | 17.000 |
| 7 | Sanuki-Awa | 18.000 |
| 7 | Owari | 18.000 |
| 9 | Mainland Asia | 23.000 |
| 10 | East | 26.000 |

**Table 7.4.** Reach centrality

| Rank | Node | Reach |
|---|---|---|
| 1 | Kinki-core | 8.500 |
| 2 | Kibi | 7.333 |
| 2 | Tsukushi | 7.333 |
| 4 | Izumo | 7.083 |
| 5 | Koshi | 6.667 |
| 5 | Taniwa | 6.667 |
| 7 | Owari | 6.167 |
| 7 | Sanuki-Awa | 6.167 |
| 9 | Mainland Asia | 5.083 |
| 10 | East | 4.667 |

**Table 7.5.** Eigenvector centrality

| Rank | Node | Eigenvec |
|---|---|---|
| 1 | Kinki-core | 0.492 |
| 2 | Kibi | 0.405 |
| 3 | Izumo | 0.387 |
| 4 | Tsukushi | 0.375 |
| 5 | Taniwa | 0.326022238 |
| 6 | Koshi | 0.326022148 |
| 7 | Sanuki-Awa | 0.243 |
| 8 | Owari | 0.144 |
| 9 | Mainland Asia | 0.101 |
| 10 | East | 0.039 |

**Table 7.6.** Flow-betweenness centrality

| Rank | Node | Betweenness |
|---|---|---|
| 1 | Kinki-core | 40.000 |
| 2 | Tsukushi | 17.500 |
| 3 | Owari | 16.000 |
| 4 | Kibi | 8.167 |
| 5 | Izumo | 6.500 |
| 6 | Koshi | 3.667 |
| 6 | Taniwa | 3.667 |
| 8 | Sanuki-Awa | 1.000 |
| 9 | East | 0.000 |
| 9 | Mainland Asia | 0.000 |

The *reach centrality measurement* (Table 7.4), indicating the smallest number of the edges which one needs to pass through in order to reach from a given node to all the other nodes in the network, shows that Kinki-core, again, is best connected, followed by Kibi, Tsukushi, Izumo, Taniwa, and Koshi.

Next, let us examine the *eigenvector centrality measurement* (Table 7.5). The method calculates the eigenvectors of individual nodes by the factor analysis method. The algorithm is complicated, but the method can be characterized to capture 'overall' patterns concerning a given network, summing up what the other measurements of centrality individually represent. Higher scores in this measurement indicate that nodes are 'more central' to the main pattern (reflected by the factor 1 eigenvectors) of distances among all of the nodes in the network. Again, Kinki-core comes out on top, followed by Kibi, Izumo, Tsukushi, Taniwa, and Koshi.

The *Betweenness centrality measurement* is the final measurement (Table 7.6). Higher scores indicate that more nodes depend on a given node to make connections with other nodes in the network. In other words, a higher score indicates that a given node *mediates* interactions between more nodes than the others in the network. Kinki-core's centrality is quite significant in this measurement, followed by the usual list of Tsukushi, Izumo, Kibi, etc. Interestingly, Owari ranks third by this measurement, because all the other nodes have to pass through Owari to go to the east.

The nodes which have consistently been ranked in higher positions in the centrality measurements—the Kinki-core, Tsukushi, and Kibi regions—were later to form the core of the IKP horizon. Amongst them, the location Kinki-core occupied in the network made it most 'central' in terms of its *connectedness* to every other node in the network and its *mediation* of interactions between other nodes (see Tables 7.1, 7.3–7.6). This suggests that once the interactions between the nodes of the network exceeded a certain volume and reached a *critical point*, Kinki-core's highest centrality in the network

inevitably had an influence on, and hence its power over, the other nodes of the network to the largest degree. This would have been particularly necessary in order to sustain and enhance the quality as well as quantity of interactions taking place between the nodes, because Kinki-core's centrality was significantly derived from its position as the most prominent *mediator* of interactions between the other nodes, as is indicated by the betweenness centrality measurement.

It is also notable that the Bonacich power measurement indicates Izumo to be best connected to those nodes which were better connected to the others (see Table 7.2). It is interesting that Izumo not only developed the unique four-tailed mortuary mound in the Yayoi V period (see Fig. 7.4 (C)) but also remained outside of the IKP horizon and maintained its distinct pottery and mortuary mound styles during the earlier Kofun period (*c.* 4th century AD ~ late 5th century AD). The elite were buried in large square or rectangular mounds, rather than in keyhole-shaped mounds. Furthermore, not only were its distinctive pots carried widely across the network but also their influence played a significant role in the emergence of the Furu-style pottery (Tsugiyama 2007: 26). Furu pottery was originated in Kinki-core and becoming widespread as a component of the IKP.

In summary, the outcomes of the centrality analyses coincide with, or 'predict', very well what the archaeological evidence shows to have occurred in the beginning of the Kofun period. This suggests that it was the *topological locations*, rather than the *character and content*, of the regional polities that significantly influenced their hierarchization and led to the formation of the centralized hierarchy in the Initial Kofun period. When the polities of western Japan came to interact with one another in the manner that led to the formation of the *large domain of various communications*, the generation of a hierarchical structure based upon different degrees of centrality between the polities was almost inevitable.

The late Yayoi V period saw the emergence of 'port-of-trade' type settlements along the Japan Sea and the Seto Inland sea coastlines where traces of the cohabitation of people coming from many of the above-mentioned nodes are recognized (e.g. Mizoguchi 1988; Kusumi 2007). It has been pointed out that some were loosely divided into residential sectors for groups from different nodes (Mizoguchi 1988). However, the relationship between the groups does not appear to have been a mutually closed and exclusive one in that their pottery assemblages comprised a mixture of both the shape-types of the regions of origin and that of the other groups sharing the settlement (Mizoguchi 1988). It is particularly interesting that the phenomenon of stylistic hybridization can often be recognized (Mizoguchi 1988). This suggests that they not only exchanged marriage partners but also developed unique hybrid group identities. In such communicative circumstances, ones that would have come into being in those port-of-trade-type settlements, it can

be inferred that the necessity of easily shared, hence symbolic and generalizable, communication media was strongly felt. A substantial portion of the communicative acts that took place in those ports-of-trade would have concerned negotiations over exchange of goods, both functional and symbolic (see items of various provenances excavated from the Nishijinmachi site, one of the ports-of-trade: e.g. Fukuoka Prefectural Board of Education 2000, 2003, 2009). Through such negotiations, the different potentialities of the communities, to which those who were involved in them belonged, would have been realized as well as felt. Through the accumulation of such communicative experiences, the necessity of a shareable set of communication media would have crystallized. It would have been the case that those who were involved in such negotiations already had experiences of negotiations of similar sorts, albeit involving people from much more limited backgrounds, and that those negotiations as communicative acts would have been mediated by the sharing of a certain set of material items, that characterized the 'horizons' mentioned above. In this way, the reproduction of an extraordinarily large domain of communications was made possible, and their *generalized symbolic communication media* eventually became invented and distributed by the group with the highest potential for the mediation of the communications; i.e. the Kinki-core polity.

In summary, the formation and certain maturation of the network on the one hand generated the differential centralities of the nodes, and on the other, necessitated the sharing of a set of generalized symbolic communication media and the supreme mediator. The Kinki-core, coming to acquire the highest centrality, naturally assumed the role, and created the IKP as the generalized symbolic media for communications.

The contents of the IKP themselves well reflected that process by signifying certain symbolic meanings. The iron tool package of the IKP often comprised: (a) weapons, (b) woodworking implements, (c) agricultural implements, and, interestingly, at times, (d) fishing implements (Fig. 7.2). They appear to represent the dominant spheres of social life in terms of the *important types of labour*: (a) communal defence, (b) the production of various wooden implements including those for agricultural works, (c) agricultural activities, and (d) fishing activities. In that sense, they metaphorically represent significant interfaces with different types of *complexities* and *contingencies* generated by both the natural and cultural environments that needed to be handled. In other words, they represent *the others* present in the life-world. Furthermore, (b), (c), and (d) might also have represented the three components of the whole life-world: (b) representing the mountain, (c) the floodplain, and (d) the sea. The body of the chief, around which the items were put, in that sense, would have been perceived as the embodiment (of the well-being) of the world.

The assemblage also often included the so-called *Sankaku* (triangular) *-en* (rimmed) *-shinju* (beastly deity-motifed) *-kyo* (mirror) mirrors (Fig. 7.2 A,

right). A fierce debate ensues on whether the typo-chronologically earlier categories of the specimens were made in the domain of the Chinese Wei dynasty or in the centre of their distribution, the present-day southern Kinki region (cf. Fukunaga 2003). Regardless of the answer, it can be safely stated that they represented an alien system of meanings and contacts with the authority and power residing *outside the domain* within which the communities (and their elite) had potential to communicate with one another.

In all, many of the attributes of the earliest keyhole tumulus, the IKP, metaphorically represented the *world*, whose integration the tumulus symbolized, their working, and their history. They also represented the three main components of the *life-world* (i.e. the mountain, the floodplain, and the sea) and distinct labours conducted in them. Furthermore, the keyhole tumulus was utterly new in terms of its gigantic scale and shape, incomparable to its regional predecessors, and hence alien to those who constructed it who were burying their elite dead there for the first time. To summarize, the earliest keyhole tumulus represented the beginning, the history of the integration, and the working, of the *world* across which the earliest keyhole tumulus and the mortuary customs that it embodied were adopted. In that sense, it can be said that the IKP encapsulated the cosmology embodying the history and structure of that world.

This 'beginning of the world' marked by the IKP continued to sustain a large-scale network of dense inter-communal interactions, whose development eventually resulted in the emergence of the ancient Japanese state some 400 years later, in the late 7th century AD.

There is also an interesting example of the formation of a fairly large interaction sphere based upon the centralized distribution of prestige goods back in the late Middle Yayoi. However, in this case, the generated hierarchy was fragile and not long-lasting. What went wrong with the predecessor of the IKP?

## 7.3 THE MIDDLE YAYOI PERIOD OF NORTHERN KYUSHU

Let us begin with the background. The rapid population increase stimulated by the establishment of a way of life based on a rice paddy-field agriculture system[6] necessitated the budding-off of small-scale settlements to previously

[6] The beginning of the Yayoi period itself is defined by the beginning of systematic rice paddy-field agriculture in the archipelago. However, at its initial stage, the distribution of the Yayoinized communities was confined to the Northern Kyushu region. Because of this, the period before the spread of the rice paddy-field agriculture-based techno-complex across western Japan is commonly described as the Initial/Incipient Yayoi period.

peripheral areas in terms of paddy-field agriculture and various social contacts (e.g. Kondo 1983, Mizoguchi 2010). The necessity of collaboration for the opening up and maintenance of paddies led to the formation of settlements comprising a complex of descent group segments (Mizoguchi 2010, 2008). Kin-based sodalities formed by such processes created an infrastructure of networks through which people, goods, and information moved. Different degrees of suitability for rice agriculture and different degrees of 'centrality' generated by the structure of the networks would have resulted in the uneven developments of such settlements (Mizoguchi 2008). Those settlements located on good agricultural lands and/or in places of high centrality grew increasingly larger and came to function as significant *nodes* for the flow of people, goods and information. Bi-local post-marital residential rule, inferred from bilinear descent system reconstructed by Yoshiyuki Tanaka's osteo-archaeological examination of skeletal remains (2002), would have encouraged micro-migrations to such 'successful' villages, and that would have further accelerated their enlargement and their acquisition of central place-like characteristics (Mizoguchi 2008).

The establishment of the Lelang and three other Early Han imperial 'commanderies' on the north-western corner of Korean peninsula in 108 BC (cf. Takakura 1995: 104–9) took place at approximately the halfway point of the Middle Yayoi period when the relationship between larger settlements and smaller settlements became that of centre and satellites. However, there was no segregated compound for elite residence, suggesting the operation of what were still fairly egalitarian social relations. These relations can be described as *heterarchical*, in the sense that some sectors of social life operated upon a hierarchical principle, and the others did not. The spatial structure of individual jar burial cemeteries of the first half of the Middle Yayoi strongly suggest that communal, collaborative principles shaped the decision regarding location for individual burials; there was no clear genealogical sequence formation, and the sharing of a linear space was of utmost importance throughout the formation process (cf. Mizoguchi 2002: 140–2).

The second half of the Middle Yayoi, however, saw the formation of genealogical burial sequences in both commoner cemeteries and elite mortuary compounds (Mizoguchi 2002: 164–80; Mizoguchi 2005). Besides, there emerged burials, located in regional centre-type large-scale settlements, deposited with rich grave-good assemblages including Han Chinese bronze mirrors and other imports as well as bronze and iron implements made locally (Fig. 7.6). It has been argued that those 'rich' burials formed an inter-regional pyramidal/conical hierarchy: at the top were famous Sugu-Okamoto (B in Map in Fig. 7.6) and Mikumo-Minamishoji jar burials (A in Map in Fig. 7.6), exclusively situated in large square mounds (30 × 20 metres in the case of the latter), and deposited with tens of Han mirrors and Han imports such as green glass discs and cross-shaped gilded bronze pegs used as wooden coffin parts,

originally decorating a coffin presented by the Emperor (cf. Takakura 1995: 143–145), indigenous bronze weapons and glass and jade comma-shaped beads, and so on (Fig. 7.6). The second-tier group includes Higashioda-Mine No. 10 jar burial, containing two Han mirrors, one large and the other small, a small, locally reworked green glass disc, and an iron dagger and an iron pin (X in Map in Fig. 7.6). The third-tier group comprises those jar burials which only have one bronze mirror each and/or iron weapons and often shell armlets and/or stone/glass comma-shaped beads (1∼17 in Map in Figs. 7.6: Kuma-Nishioda Loc. 13, No. 23 (9 in Map) is shown as an example).

Their distribution, in which the Mikumo and the Sugu were surrounded by the second- and third-tier burials sites (Fig. 7.6), appears to reflect the presence of a conical-hierarchical structure, and it is commonly accepted that the relationship between those tiers was one of institutionalized domination and subordination (Shimojo 1991; Nakazono 1991). However, the second-tier burials seem to be located at important *crossroads* of interaction as seen from the Sugu and Mikumo, rather than at the central place-like settlements of areas with high productive potentials. For instance, the Higashioda-Mine is situated on the southern entrance of the Futsukaichi path connecting the coastal plains of the Genkainada sea with the Chikushi plain (X in Map in Fig. 7.6). A third-tier burial, the Kuma-Nishioda, is situated less than two kilometres away (9 in Map in Fig. 7.6). Two third-tier burials, Futsukaichi-Mine (7) and Dojoyama (8) are also situated close to the northern entrance of the path, also less than three kilometres away from one another, as if flanking the path. Another such pocket in the concentration of rich burials exists on the southern foot of the Seburi mountain range where the Futatsukayama (14) and the Yoshinogari (15) are situated around two kilometres away from one another (in Map in Fig. 7.6). Two mountain paths crossing the Sefuri, one connecting the area to the vicinity of the Sugu, the other to the Itoshima plain where the Mikumo-Minamishoji is situated, come out to the plain in their vicinity. The Tateiwa, where one jar burial (Burial No. 10) contained six large bronze mirrors and four other jar burials also contained one mirror each, is situated at the centre of the riverine basin of the Onga, connecting the coastal plains of the Genkainada sea with that of the western Seto Inland sea (Y in Map in Fig. 7.6). They may suggest that the seeming conical-hierarchical structure may have resulted from *strategic gift-giving* by those first-tier communities and their chiefly figures to that of the communities that were recognized by the former as strategically important partners.

In order to examine this hypothesis, we have calculated the *network centrality* of the communities with the Han mirror-deposited burials, and those with the burials deposited with iron halberds, which are likely to have been distributed by the Sugu elite (cf. Murakami 1998: 78–84). These have been calculated (Fig. 7.7, Tables 7.7–7.12) using UCINET Ver. 6.239 (cf. Borgatti et al. 2002). Our analytical premises are that: (1) dense interactions had been taking place between the

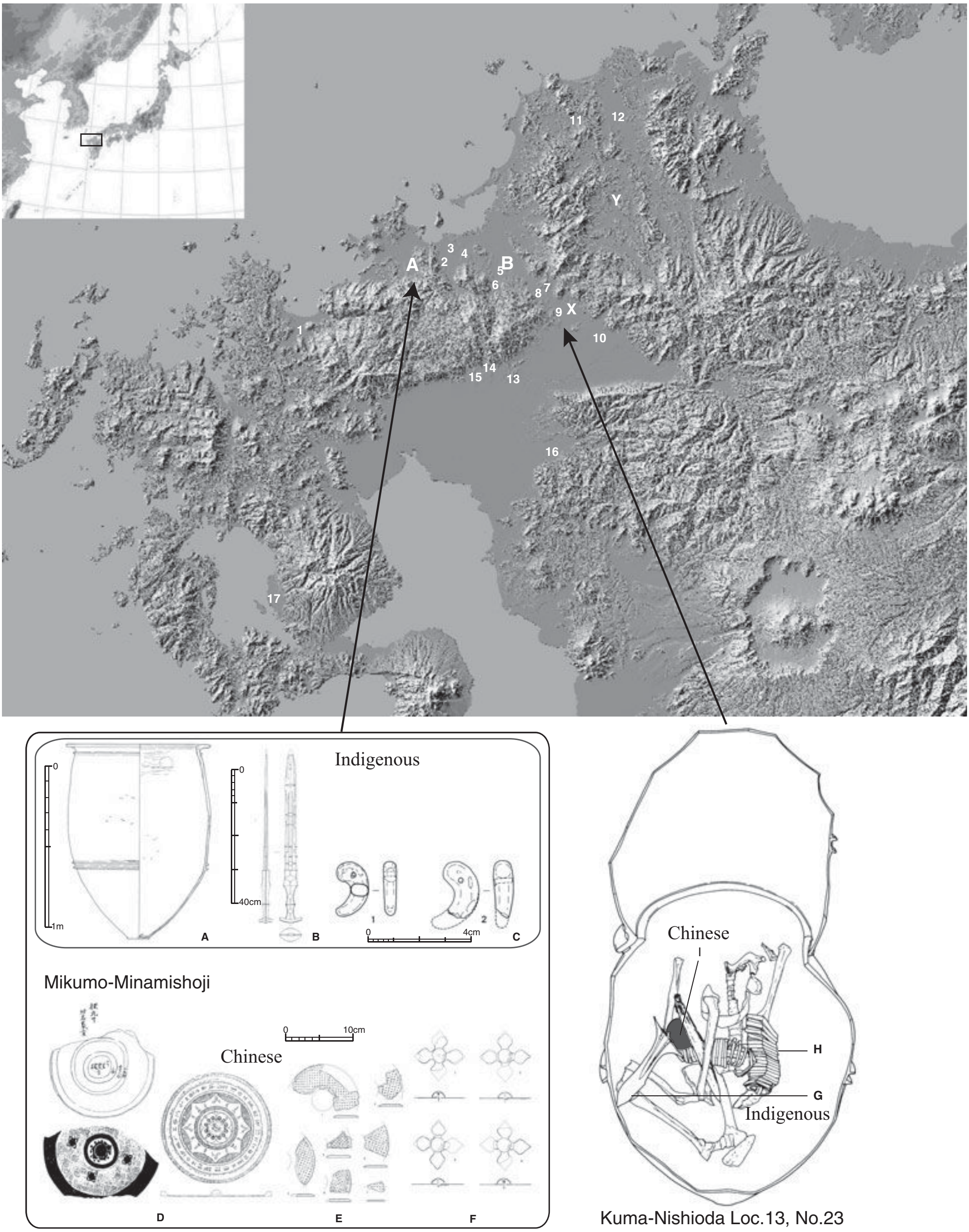


**Fig. 7.6.** The distribution of jar burials with grave goods including Chinese bronze mirrors and other Chinese imports and/or iron weapons. Map: A and B indicate burials with a large number (more than seven) Early Han bronze mirrors and other Chinese and indigenous artefacts ('First-tier burials'). X and Y indicate burials with more than two Early Han bronze mirrors and/or a small number of Chinese and indigenous artefacts ('Second-tier burials'). 1∼17 indicate burials with either one Early Han bronze mirrors and indigenous artefacts or indigenous artefacts including iron weapons ('Third-tier burials'). A Mikumo-Minamishoji, B Sugu-Okamoto,

nodes (i.e. the communities having the burials) before the distribution of the items as symbolically generalized communication media began; (2) differential centralities had already been generated when the distribution began, and (3) the distribution was designed by those nodes which had already achieved a higher centrality than the others in the manner which basically followed the pre-generated centralities, and was reflected by the different contents of the prestige good assemblages. Drawing upon those premises, we will compare the outcome of the analysis to the actual distribution pattern of the rich burials with different prestige good assemblages.

The results showed that both of the first tier burials—the Sugu and the Mikumo—consistently scored high centrality readings in the measurements used, although they did not enjoy absolute overall dominance. Interestingly, some third-tier burials such as the Rokunohata, the Futatsukayama, the Futsukaichi, and the Kuma-Nishioda (in Closeness: Table 7.9), and the Futatsukayama, the Rokunohata, and the Yoshinogari (in Reach: Table 7.10), scored as high as, or even higher than, the first- and second-tier burials in some measurements.[7] It is also extremely interesting that the Mikumo scored less highly, except in Eigenvector Centrality. It should be added that the extremely high betweenness centrality score of the Sugu (Table 7.12) suggests that its prominence derived significantly from its topological position as the *most prominent mediator* in the emergent network.

The outcome has various implications, but I would like to note in particular that the first-tier communities, the Mikumo and the Sugu, did not necessarily enjoy the positions with the highest centrality. In terms of the potential of influence generated by the topological structure of the network, some of the second- and third-tier communities, such as the Futatsukayama, the Rokunohata, the Yoshinogari, and so on, were ranked higher. This suggests

X Higashioda-Mine, Y Tateiwa-Hotta, 1 Kashiwazaki and Nakabaru, 2 Yoshitake-Hiwatashi, 3 Arita, 4 Maruodai, 5 Monden-Tsujibatake, 6 Antokudai, 7 Futsukaichi-Mine, 8 Dojoyama, 9 Kuma-Nishioda, 10 Kuriayama, 11 Fuchibaru-Umenoki, 12 Noboritate, 13 Rokunohata, 14 Futatsukayama, 15 Yoshinogari, 16 Chanokinomoto, 17 Tominoharu. *16 and 17 are dated to the early Late Yayoi, but probably brought to there during the late Middle Yayoi. Below: A Mikumo-Minamishoji jar burial No. 2 (lower jar), B Bronze dagger from burial No. 1, C Jade comma-shaped beads, D Bronze mirrors from burials No. 1, E *Heki* green glass discs from burial No. 1, F Star-shaped gold-gilded iron coffin ornaments from burial No. 1, G Bronze halberd from Kuma-Nishioda Loc. 13, burial No. 23, H Shell armlets, I Bronze mirror. A~F: from Fukuoka PBE 1985, G~I: Chikushino MBE 1993.

[7] The high scores that the Yoshitake and the Arita achieved in Bonacich centrality measurement (Beta factor 0.5) can be explained by their connection with well-connected nodes such as Sugu and Mikumo, and should be treated separately from the readings of the other measurements.

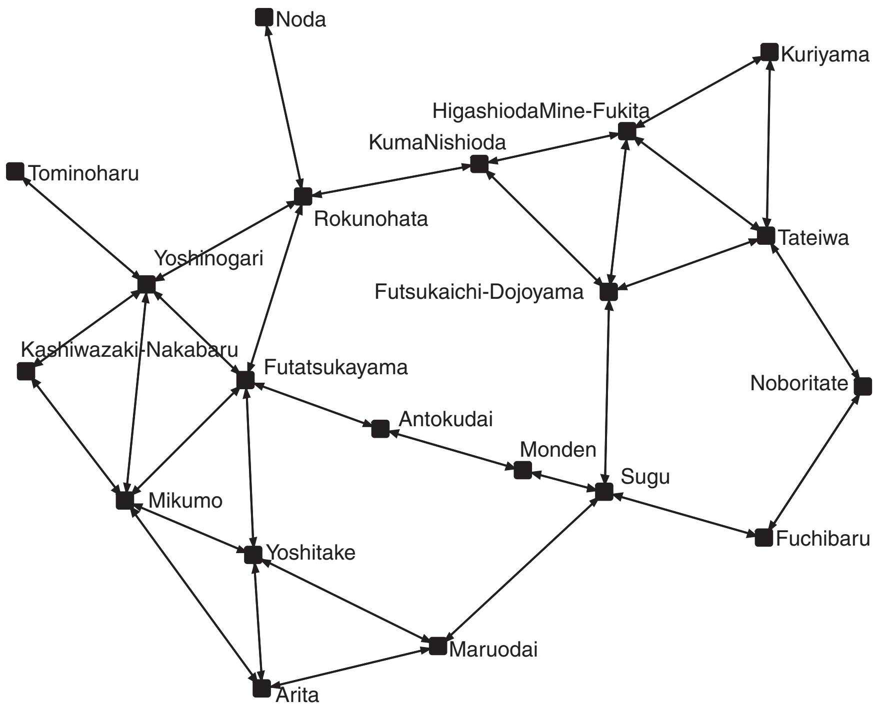


**Fig. 7.7.** Network of rich jar burials of the Yayoi IV. 'Edges' are basically drawn between the neighbouring 'nodes', but other archaeological-contextual information is also taken into account (after Mizoguchi 2010). The graph is generated by NetDraw (in UCINET Ver. 6.239: Borgatti et al. 2002), and the locations of the edges do not reflect their exact locations on the site distribution map, provided in Fig. 7.6.

the significance of exclusive contacts with the empire, through contacts with its commandery of Lelang, as the source of authority and hierarchization indicated by the hierarchical distribution of the grave goods.

The above shows that the network hierarchy that emerged did not necessarily reflect the *topological structure and potential* of the network in a straightforward manner. Rather, the formation of the network itself, as well as its hierarchization, was significantly derived from contacts with the Han Empire, that resulted in inter-communal differences in the form of differential accessibility to the Lelang commandery.

The contents of the distributed prestige good assemblage were dominated by the items indicating exclusive access to authorities outside of the communicative domain (i.e. the Han Empire and communities of the Korean peninsula), although one can recognize attempts to incorporate indigenous symbols and to create unique *internal/indigenous* prestige items, for instance, in the form of shell armlets (Fig. 7.6).

**Table 7.7.** Degree centrality

| Rank | Node | Degree |
|---|---|---|
| 1 | Futatsukayama | 5,000 |
| 1 | Mikumo | 5,000 |
| 1 | Yoshinogari | 5,000 |
| 4 | Futsukaichi-Dojoyama | 4,000 |
| 4 | HigashiodaMine-Fukita | 4,000 |
| 4 | Rokunohata | 4,000 |
| 4 | Sugu | 4,000 |
| 4 | Tateiwa | 4,000 |
| 4 | Yoshitake | 4,000 |
| 10 | Arita | 3,000 |
| 10 | KumaNishioda | 3,000 |
| 10 | Maruodai | 3,000 |
| 13 | Antokudai | 2,000 |
| 13 | Fuchibaru | 2,000 |
| 13 | Kashiwazaki-Nakabaru | 2,000 |
| 13 | Kuriyama | 2,000 |
| 13 | Monden | 2,000 |
| 13 | Noboritate | 2,000 |
| 19 | Noda | 1,000 |
| 19 | Tominoharu | 1,000 |

**Table 7.8.** Bonacich power centrality

| Rank | Node | Power |
|---|---|---|
| 1 | Yoshitake | 182.7117 |
| 2 | Arita | 174.271 |
| 3 | HigashiodaMine-Fukita | 162.5672 |
| 4 | Mikumo | 145.4643 |
| 5 | Tateiwa | 141.8231 |
| 6 | Maruodai | 140.3661 |
| 7 | Futsukaichi-Dojoyama | 139.752 |
| 8 | Kuriyama | 112.1951 |
| 9 | KumaNishioda | 91.36418 |
| 10 | Futatsukayama | 65.32209 |
| 11 | Kashiwazaki-Nakabaru | 44.69597 |
| 12 | Sugu | 43.74958 |
| 13 | Noboritate | 29.13192 |
| 14 | Yoshinogari | 23.92769 |
| 15 | Rokunohata | 0.409286 |
| 16 | Fuchibaru | −3.55927 |
| 17 | Tominoharu | −8.03617 |
| 18 | Noda | −19.7954 |
| 19 | Antokudai | −21.8688 |
| 20 | Monden | −29.0597 |

**Table 7.9.** Closeness centrality

| Rank | Node | Closeness |
|---|---|---|
| 1 | Rokunohata | 44 |
| 2 | Futatsukayama | 45 |
| 3 | Futsukaichi-Dojoyama | 46 |
| 3 | KumaNishioda | 46 |
| 5 | Sugu | 47 |
| 6 | Maruodai | 49 |
| 6 | Yoshinogari | 49 |
| 6 | Yoshitake | 49 |
| 9 | HigashiodaMine-Fukita | 52 |
| 9 | Mikumo | 52 |
| 11 | Antokudai | 53 |
| 11 | Monden | 53 |
| 13 | Arita | 54 |
| 14 | Tateiwa | 58 |
| 15 | Fuchibaru | 61 |
| 15 | Kashiwazaki-Nakabaru | 61 |
| 17 | Noda | 62 |
| 18 | Kuriyama | 67 |
| 18 | Noboritate | 67 |
| 18 | Tominoharu | 67 |

**Table 7.10** Reach centrality

| Rank | Node | Reach |
|---|---|---|
| 1 | Futatsukayama | 11.44999981 |
| 2 | Rokunohata | 11 |
| 3 | Yoshinogari | 10.98333359 |
| 4 | Sugu | 10.78333187 |
| 5 | Futsukaichi-Dojoyama | 10.74999905 |
| 6 | Mikumo | 10.68333244 |
| 7 | Yoshitake | 10.44999886 |
| 8 | KumaNishioda | 10.24999905 |
| 9 | HigashiodaMine-Fukita | 9.999999046 |
| 10 | Maruodai | 9.916666031 |
| 11 | Tateiwa | 9.599999428 |
| 12 | Arita | 9.449999809 |
| 13 | Antokudai | 9.11666584 |
| 14 | Monden | 9 |
| 15 | Kashiwazaki-Nakabaru | 8.599999428 |
| 16 | Fuchibaru | 8.516667366 |
| 17 | Noboritate | 8.133333206 |
| 18 | Kuriyama | 7.950000286 |
| 19 | Noda | 7.733333588 |
| 20 | Tominoharu | 7.600000381 |

**Table 7.11.** Eigenvector centrality

| Rank | Node | Eigenvec |
|---|---|---|
| 1 | Mikumo | 0.44731 |
| 2 | Futatsukayama | 0.428956 |
| 3 | Yoshinogari | 0.395506 |
| 4 | Yoshitake | 0.357763 |
| 5 | Rokunohata | 0.273709 |
| 6 | Arita | 0.26734 |
| 7 | Kashiwazaki-Nakabaru | 0.225118 |
| 8 | Maruodai | 0.19582 |
| 9 | Antokudai | 0.131676 |
| 10 | KumaNishioda | 0.127168 |
| 11 | Sugu | 0.108026 |
| 12 | Futsukaichi-Dojoyama | 0.107838 |
| 13 | Tominoharu | 0.10564 |
| 14 | HigashiodaMine-Fukita | 0.094556 |
| 15 | Tateiwa | 0.073985 |
| 16 | Noda | 0.073108 |
| 17 | Monden | 0.064025 |
| 18 | Kuriyama | 0.045018 |
| 19 | Fuchibaru | 0.036754 |
| 20 | Noboritate | 0.029579 |

**Table 7.12.** Flow-betweenness centrality

| Rank | Node | FlowBet |
|---|---|---|
| 1 | Sugu | 120.0667 |
| 2 | Tateiwa | 62.66667 |
| 3 | Rokunohata | 62.56667 |
| 4 | Yoshinogari | 60.46667 |
| 5 | Futatsukayama | 55.83333 |
| 6 | Antokudai | 39.73333 |
| 6 | Monden | 39.73333 |
| 8 | Mikumo | 39 |
| 9 | Fuchibaru | 38.83333 |
| 9 | Noboritate | 38.83333 |
| 11 | HigashiodaMine-Fukita | 29 |
| 12 | KumaNishioda | 26.16667 |
| 13 | Maruodai | 25.23333 |
| 14 | Futsukaichi-Dojoyama | 17.83333 |
| 15 | Yoshitake | 13.06667 |
| 16 | Arita | 8.566667 |
| 17 | Kashiwazaki-Nakabaru | 1.9 |
| 18 | Kuriyama | 1.5 |
| 19 | Noda | 0 |
| 19 | Tominoharu | 0 |

Why, then, did the exclusive access to the commandery and the items that signified access have such potential for forming an internally hierarchized network? In order to answer this question, we need to consider the nature of the authority of the period. The establishment of a rice paddy-field agriculture-based social system narrowed down the range of uncertainties and contingencies with which society had to cope. Before this, in the Jomon period, a range of natural resources was exploited for subsistence, and the differential uncertainties they generated needed to be managed (cf. Mizoguchi 2002: ch. 4). The exploitation of many of these continued after rice paddy-field agriculture-based lifestyles were established. However, the latter came to occupy a much larger portion of the spatio-temporal matrix of social life, and it can be inferred that the endeavour to reduce the uncertainty and contingency of the world became increasingly focused on rice production activities. I would argue that this is a significant cause of the development of rituals concerning the annual cycle of rice farming, particularly well embodied by the pictorial representations on some *Dotaku* bronze bells (see e.g. Sahara 1982). It can be inferred that such rituals would have also served as occasions for various social negotiations, and those who conducted the rituals would have acted as the mediators of such negotiations. The authority of such 'shaman-leader' figures would have derived from the *effect* of their deeds; i.e. the reduction of the uncertainty and contingencies involved in rice farming, *and*, increasingly, social negotiations.

Whereas the former were determined by uncontrollable natural forces, the latter could be significantly influenced by the differential abilities of the individuals concerned. In that sense, the successful conduct of social negotiations would have increased their importance for the shaman-leaders to consolidate and enhance their authority. In that regard, contacts with the newly established commandery would have emerged as a new and important source of such authority. The commandery, which represented the Han Empire, the 'civilization' which the northern Kyushu population encountered almost for the first time, would have been perceived as something like the force of nature as at the same time as something which was not entirely uncontrollable, because it, after all, comprised, and was run by, human beings. Therefore, if someone who conducted agricultural rituals and mediated daily social negotiations could successfully manage negotiations with such an entity, this would have significantly enhanced their authority, proving their capacity to manage something akin to the force of nature.

I would argue that the proof of the ability of controlling the force of something akin to nature was a determinant ingredient of 'prestige goods' in general. If this were indeed the case, it also suggests the potential vulnerability of the emergent hierarchical order. The sole 'proof' of someone else's ability to control this quasi-natural force was the constant procurement and distribution of Han Chinese bronze mirrors and allied material items. Therefore, once the supply of Han mirrors and other goods was cut off due to the temporary takeover by the Xing dynasty of the Han (9–23 AD), the network hierarchy

appears to have collapsed. It is well attested by the collapse of regional hierarchical settlements systems (cf. Ozawa 2000).

## 7.4 CONCLUSION

In conclusion, I would like to propose a model of the evolution of prestige good systems, from one based solely upon actual control over access to the *Other* as the source of authority and prestige to one based upon control over mediation with the *transcendental* of some sort. The former, exemplified by our Yayoi case, tends to be associated with an emergent hierarchy, and the latter, exemplified by the Kofun case, a fairly mature hierarchy. Let us call the former the 'primitive' prestige good systems, and the latter, the 'mature' prestige good systems.

The goods of the mature type tend to symbolise the elements, and most likely their orderly working, of the *world*, or, the well-being of the *life-world*, as well as contacts with the Empire. As illustrated, the IKP (i.e. the Initial Kofun Package) represents the dominant spheres of social life in terms of the *important types of labour*: (a) communal defence (represented by weapons), (b) the production of various wooden implements including those for agricultural works (represented by wood-working tools), (c) agricultural activities (represented by agricultural tools), and (d) fishing activities (represented by fishing implements) (see Fig. 7.2). Besides, (b), (c), and (d) may also have represented the three components of the whole life-world: (b) representing the mountain, (c) the floodplain, and (d) the sea. The body of the chief, around which the items were placed, in that sense, would have been perceived as the embodiment (of the well-being) of the world. The so-called *Sankaku* (triangular)-*en*(rimmed)-*shinju*(beastly deity-motifed)-*kyo* (mirror) mirrors, another important component of the package, represented the Wei Empire of China.

The material media mobilized in the 'primitive' prestige-good systems tend to be constituted by the items that indicate direct contacts to the *Other* in a straightforward manner, in the form of a polity/polities tending to have developed far higher social complexity and technological achievements than the recipient itself (see Fig. 7.6). In our northern Kyushu Yayoi case, this was the Han Empire of China and its commandery of Lelang. The commandery was situated on the north-western part of the Korean peninsula, and the contents of the prestige-good assemblage were either imported or locally created by employing technologies introduced from there in a straightforward manner, representing direct control with the source(s) of authority.

It would have been functionally advantageous to shift the source of authority from something *external* and *real* to something *internal* and *imaginary*. The authority based upon the former was bound to be instable, due to the

cyclical rise and fall of the empires. In contrast, the authority based upon the latter would have been stable, because the latter was an imaginary construct. Of course, the emergence of the latter was derived from the abstraction of the function of the elite, which resulted from the stabilization of social hierarchy and vast enlargement of the scale of communication sphere. What is important to note is that the shift would have taken place through the accumulation of trial-and-error episodes, and in that sense, would have been achieved unconsciously, or as an 'unintended consequence'.

The mature prestige-good systems effectively exempted themselves from cyclical growth and collapses, and once achieved, a peripheral entity was ready to develop into a 'state'. And some of them, including the ancient Japanese state, tried to further become empires themselves.

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# Part III

# Material Culture

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# 8

## The Dynamics of Social Networks in the Late Prehispanic US Southwest

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### 8.1 INTRODUCTION

One of the most fundamental areas of archaeological research concerns how people interact with each other, with things, and with the landscape. A relational approach has become important to our work, and our professional vocabularies are replete with concepts such as 'interaction spheres', 'world systems', 'communities of practice', and 'networks'.

Archaeology is not the only discipline that is interested in relations or in networks, however, and in this chapter we take an interdisciplinary perspective that focuses on the application of social network analysis (SNA). SNA is a field that is rich in theory and method, specifically focuses on relations between units, and has much potential for archaeological applications. SNA has been most widely developed in quantitative sociology, where it is used to look at the relationships or ties between various kinds of actors (see Breiger 2004; Carrington et al. 2005; Newman et al. 2006; Scott 2000; Wasserman and Faust 1994, for overviews). Nonetheless, SNA uses many concepts of potential interest to archaeologists. These include: (1) centrality (and its relationship to social capital), (2) embeddedness, (3) strength of ties and structural holes, (4) the presence of cliques and other subgroups, and (5) diffusion and social influence. The relative lack of SNA applications to archaeological data is especially ironic since anthropological studies of kinship and other social and economic dimensions of societies were one source of many of social network theory's basic principles (Freeman 2004; Scott 2000).

The chapters in this volume as well as a growing number of other applications in archaeology show that network approaches have a great deal of potential for interpreting archaeological data—especially at the regional scale (e.g. Bentley and Shennan 2003; Brughmans 2010; Graham 2006; Isaksen

2008; Knappett et al. 2008; Munson and Macri 2009; Sindbæk 2007). When coupled with Geographic Information Systems (GIS), network analysis explores the correlations between spatial geography and social, economic, and political landscapes.

Not all archaeological data and methods are amenable to SNA, but there are several advantages to taking an SNA approach to archaeological data. First, it emphasizes the ties or relations among archaeological sites rather than focusing on the site itself as the unit of analysis. Second, it provides a set of formal methods for characterizing different kinds of networks. SNA can help to address how sites relate to each other based on their associative properties, rather than assumed relations based on only spatial distance. Put another way, we might ask: does social distance correlate with spatial distance and what are the causal factors when it does not? But perhaps even more important is the ability of archaeology to provide a view of network change over time. This permits a dynamic approach to social network analysis across centuries that is absent in contemporary social network studies. When we add the temporality of social networks, we have a powerful way of looking at how social position and geography may influence future configurations. As Stephen Borgatti and his colleagues recently noted, 'the most fundamental axiom in social network analysis research is that a node's position in a network determines in part the opportunities and constraints that it encounters, and in this way plays an important role in a node's outcomes' (Borgatti et al. 2009: 894).

In this chapter we conduct SNA on two case studies from the late pre-Hispanic US Southwest. We take a diachronic perspective, so that we can look at network dynamics over a 200-year period (AD 1200 to 1400). The case studies that we have chosen are areas where, through independent data, extensive migration has been demonstrated and is widely accepted. Our analyses pertain to three specific topics of archaeological interest: (1) first-comer advantage within a social landscape of migration, (2) the relationship of spatial to social centrality, and (3) node persistence or resilience over time. We focus on two geographically circumscribed areas of central and south-eastern Arizona, the San Pedro Valley and the Tonto Basin, which have been intensively studied by archaeologists over the past two decades. Although both areas saw periods of migration, the outcomes were very different. Because of the temporal control allowed by decades of archaeological research in the Southwest, including tree-ring dating, we are able to divide our 200-year time span into 50-year 'snapshots' to look at changes over time.

By highlighting methodological issues in the archaeological application of SNA, our case studies also have implications beyond the Southwest. Several issues that we discuss are archaeological methods for defining connectivity, what these connections mean in terms of network flow, the choice of statistics

to measure network properties, and how to assess the robustness of these statistics.

## 8.2 THE ARCHAEOLOGICAL CONTEXT

Our data come from the massive Southwest Social Networks (SWSN) Database, which now contains archaeological information on over 1,600 residential sites of thirteen rooms or more dating between AD 1200 and 1500 in western New Mexico and most of Arizona.[1] This time period roughly corresponds to the Classic period of the southern Southwest and the late Pueblo III and Pueblo IV periods of the northern Southwest. The interdisciplinary SWSN project is designed to look at social networks at various scales using the distribution of a variety of different archaeological materials to reconstruct the social ties that influenced these distributions.

Although the analyses themselves can be quite complex, the basis of all network analyses is very simple: nodes and ties. In our database, residential sites or settlements are the nodes and the ties are based on different kinds of artefacts: particularly decorated and plain ceramics, and obsidian. Nodes were originally defined based on an earlier database, the Coalescent Communities Database (CCD) (Hill et al. 2004) that was a GIS of over 2,300 sites that included location, size, and occupation range for every major settlement in the US Southwest from AD 1200 to AD 1700. Because of the size of that database, we have limited our project area to those settlements west of the Continental Divide and dating AD 1200 to 1500. Besides verifying and refining data on location, date, and number of rooms that were part of the original CCD, the SWSN project has added nodal attributes including public architecture and drainage or watershed. We consider drainages as geographically circumscribed areas that placed spatial constraints on interaction and have the potential to be verified with SNA in the future.

The links or connections between sites draw on ceramic data from 686 of the 1,600 settlements west of the Continental Divide in the CCD, comprising approximately 4.3 million ceramic artefacts attributable to 415 ceramic types within 81 wares. In the Southwest, wares are defined by technological variability and are largely geographically clustered. A single ware may have multiple ceramic types, which are most often stylistically based and temporally sequenced within wares (although there are exceptions). For the ceramics in our database, we have focused on wares over types because of potential

[1] In a few intensively studied regions, including the Tonto Basin discussed in this chapter, comparably collected data are available for sites smaller than thirteen rooms and were added to the database. But in all cases we only used sites with a sample size of at least thirty sherds.

inconsistency in type identifications among different researchers, as well as the sheer number of types involved, but types are retained in the database for temporal control at varying levels. We reassessed date ranges for all types and wares encountered in the various data sources we examined, and developed a common synonymy. Original ceramic identifications of the individual projects are preserved as metadata in the database. Collection methods are also in the database to distinguish sites that were systematically sampled in some way, whether surface or subsurface. In addition to the ceramics, nearly 5,000 geochemically sourced obsidian artefacts from 133 sites using X-Ray Fluorescence analyses (Shackley 2005) are in the database, although these are not considered in the current chapter.

Although ceramics are often treated as a single class of objects, we consider decorated and undecorated ceramics separately because we think that these were produced and used in different social contexts and circulated through different social networks. For example, polychrome ceramics, for which this period is well known, were produced in more restricted numbers of villages and households within villages (e.g. Triadan et al. 2002) than plain ceramics. Many of them have been shown to have had ideological significance (Crown 1994; Van Keuren 2001) and were used in public events such as feasting (Mills 2007). Non-decorated or 'plain ware' ceramics (including red-slipped and corrugated) were largely used as storage and cooking vessels, and to a lesser degree as serving vessels in the Southwest. For the time period and geographic area that we consider here, most of these vessels were made in considerably less specialized production contexts and were more likely to have been used in daily household activities rather than in public displays. We believe that the different communities of practice (Lave and Wenger 1991; Wenger 1998) that produced, distributed, and used decorated and plain ceramics in the Southwest represent different social networks that can be identified through SNA. Comparison of networks based on similarities in decorated and non-decorated ceramics is one of the major points that we make in the analyses below.

In this chapter we focus on the San Pedro Valley and the Tonto Basin—two areas of southern Arizona that have been particularly well studied and with well documented demographic and social changes that include migration, coalescence, ethnic co-residence, craft specialization, diversification of ritual architecture, ideological transformation, and, ultimately, depopulation (Clark 2001; Clark and Lyons 2012; Hill et al. 2004). There are several reasons to think that individuals living in adjacent or nearby settlements may not always share the same associations or participate in communities of practice in exactly the same way. This has become especially apparent when studying the late prehispanic period in the Southwest because of widespread population movements. Some of these movements were part of a diasporic migration from the northern Southwest to the central and southern Southwest during the

late AD 1200s that is now being examined by many researchers working in a number of different locations throughout the region (Mills 2011). In the 1950s, Emil Haury convincingly demonstrated the presence of a late 13th-century enclave of immigrants from northeastern Arizona at Point of Pines, a large settlement in east-central Arizona (Haury 1958). Archaeologists (Clark and Lyons 2012; Di Peso 1958) have also documented the presence of several communities from northeastern Arizona that migrated into the San Pedro Valley in south-eastern Arizona, producing distinctive ceramics and retaining the architectural traditions of their homeland. Once seen as anomalies, these migrations are now viewed as part of the social context that accompanied major changes in the Classic period of the southern Southwest and during the late Pueblo III and Pueblo IV periods of the northern Southwest.

## 8.3 CONSTRUCTING NETWORK TIES

One of the first decisions in applying network analysis to artefacts from archaeological sites is how to take the data generated by different projects to form ties (or not). A guiding premise is that sites should be tied when their ceramic assemblages are similar; that is, network relations between sites are indicated by ceramic similarity. For each settlement node within our database we have counts of ceramics (divided as noted above into ceramic wares, and the overarching categories of decorated vs. plain). These raw counts are apportioned into each 50-year time period during which a site was occupied using a method in Roberts et al. (2012).[2] These data are treated as a matrix and (dis)similarity scores are calculated on each pair of sites at each 50-year period. Writing $f_{ij}$ for the count of ware $j$ at site $i$ and $f_{i+}$ for the total count of the relevant set of wares (that is, either the set of decorated or the set of undecorated) at site $i$, the dissimilarity index for sites $i$ and $i^*$ is

$$D_{ii^*} = \sum_j |(f_{ij}/f_{i+}) - (f_{i^*j}/f_{i^*+})|/2 \qquad (8.1)$$

where the sum is over all the wares in the set. This dissimilarity index is equivalent to the Brainerd–Robinson coefficient that is widely used in archaeology and has been argued to be particularly effective for comparison of counts of nominal categories (e.g. Cowgill 1990). Differences in the scale (the dissimilarity index ranges from 0 to 1) and direction (a larger dissimilarity index indicates less similarity) of the two measures are purely cosmetic.

[2] We use the Normal (−2, 2) method described in Roberts et al. (2012). If the beginning or end year of a site's occupation period is a multiple of 25 but not 50, we first apportion ceramic counts into 25-year periods and then aggregate these shorter periods into the 50-year periods used in our analysis. Also, we apportion data on types and then aggregate into wares.

A second important decision is how to use dissimilarity scores to define ties and calculate network statistics. In this chapter we treat the 'raw' dissimilarity scores as indicating valued relations between sites (because a greater dissimilarity index indicates less similarity, we measure the relation between two sites by $(1-D_{ii^*})$). We calculate one measure of centrality, eigenvector centrality, using these values. But we also consider a way to binarize these values to indicate presence and absence of non-valued ties, and use these ties to construct network diagrams. Visual displays have advantages for understanding/viewing network topology but there are trade-offs. One of these is the reductive nature of any presence/absence decision, which certainly discards useful information. The other difficulty is developing a consistent and meaningful cut off for what constitutes a tie (e.g. the value of the dissimilarity index that defines the top 10 per cent most similar pairs of sites, or the top 25 per cent, etc.).

## 8.4 NODE CENTRALITY

Centrality measures that attempt to differentiate nodes by their structural prominence are key elements of SNA (Freeman 1979; Wasserman and Faust 1994). In general, highly central nodes appear more 'important' with respect to the structure of the network, but the nature of this importance depends on the technical definition of a particular centrality measure.

There are several ways to calculate centrality including:

- degree centrality: using the number of ties, so that actors with more ties are more central/powerful because they can directly affect/influence more actors (especially those who do not have as many ties themselves);
- closeness centrality (including eigenvector centrality): using the network distance of an actor to all other actors in terms of the overall structure of the network; and
- betweenness centrality: using the position of an actor in terms of its presence on network paths between other pairs of actors.

Although numerous centrality measures have been proposed, Borgatti (2005) and Butts (2009) emphasize that a given measure may be more or less appropriate substantively, depending on what is thought to be flowing through a network and how. Many kinds of transmission processes can distribute and consume ceramic vessels of specific wares and types, including physical exchange, emulation among interacting groups of potters, and the appropriate social contexts in which to use and consume specific types of vessels. In the present case, with nodes representing settlements and ties indicating similarity of ceramic assemblages, several different conceptions of

the relation inherent in the ties seem plausible. These conceptions would in turn suggest different types of flows of the sort considered by Borgatti (2005), and therefore lead to different choices of centrality measures.

If we consider ceramics as an efficient package delivery process in which the transfers are through the shortest paths between nodes, then betweenness centrality may be the best measure. Without production source determinations on many ceramic artefacts, however, we cannot definitively establish that such deliveries occurred between two sites even though they are linked in our analysis by ceramic similarity. Instead we can only infer participation in a larger social and economic network through production, trade, and/or emulation. If we are interested in flows of information about ceramics through communities of practice—with attitudes or beliefs influencing the transfer of ceramics and distribution practices that may not follow the most efficient delivery process (e.g. gifts between relatives that live at some distance)—then closeness centrality may be a more appropriate measure. Here we focus on eigenvector centrality (Bonacich 1972). This measure is frequently used because of its substantive appeal and its applicability to very large networks with multiple flow processes (including, for example, Google page ranks). In addition, it is a measure that takes the structure of the whole network into consideration, and its calculation does not require that ties be binarized.

We believe eigenvector centrality more accurately captures the complex flow processes we are measuring by similarities in ceramic assemblages. An important candidate for the meaning of the ties inferred from these similarities is that a tie indicates the extent of site inhabitants' participation in a common ideology or cultural system (Crown 1994; Mills 2007). More generally, the ties may convey social influence, possibly mutual in nature. This conception of ties, and their role in conveying (possibly) mutual social influence, suggests the use of eigenvector centrality. Borgatti (2005: 62) noted that 'the measure does not in any way assume that things flow by transferring or by replicating to one neighbor at a time. Rather, it is consistent with a mechanism in which each node affects all of its neighbors simultaneously, as in a parallel duplication process.' As the ties among the sites do not necessarily indicate trade in goods, or direct personal interaction among inhabitants, this image of parallel duplication is a close fit with processes of cultural transmission thought to be at work among these communities.

Under eigenvector centrality, a node's score is proportional to the sum of its neighbours' scores:

$$c_i \propto \sum_j a_{ij} c_j \tag{8.2}$$

where $c_i$ represents node $i$'s centrality score, and $a_{ij}$ represents the entry of the adjacency matrix indicating the presence or value of a tie (undirected, or symmetric, in our case) between nodes $i$ and $j$. As noted above, here we do not

binarize ties between sites as 'present' or 'absent' before analysing the network, so $a_{ij}$ is not restricted to the values 1 and 0. Instead $a_{ij}$ is the measured similarity between the (time-apportioned) assemblages at sites *i* and *j*; that is, in terms of the dissimilarity indices, $a_{ij} = 1 - D_{ij}$, so that there is in effect no tie between two sites whose assemblages do not overlap at all (if $D_{ij} = 1$, then $a_{ij} = 0$), and in other cases, the weight on the tie is greater as the assemblages are more similar.[3] Under this measure, a node that is closely tied to highly central alters will itself be highly central. It can be shown that the eigenvector associated with the largest eigenvalue of the adjacency matrix A yields the desired scores (Bonacich 1972).

## 8.5 CASE STUDY 1: THE SAN PEDRO VALLEY

The San Pedro Valley is a well-studied area of the southern Southwest and is an optimal case study for several reasons. First, the Center for Desert Archaeology tested 27 sites representing almost all of the known major sites in this circumscribed region that date to our period of interest (Fig. 8.1). Second, the recovered materials were analysed using consistent laboratory protocols. Third, many of the sites were occupied for more than one 50-year period, which allows us to relate node persistence to network characteristics. And fourth, the valley includes classic cases of migration—entire villages that are attributed to the movement of people from north-eastern Arizona in the late 13th century, forming enclaves within the valley (such as Davis Ranch and Reeve Ruin) (Clark and Lyons 2012; Di Peso 1958). Non-migrant sites have distinctive compound architecture and one of the results of immigrants moving into the valley was the construction of a new kind of public architecture in local communities, the platform mound. By contrast, room-block architecture is evidence of migrants and is correlated with kivas and other hallmarks including distinctive polychrome ceramics and perforated plates (the latter used in pottery production) (Lyons and Lindsay 2006). As with many areas of the Southwest, the San Pedro Valley saw dramatic depopulation and out-migration before the arrival of Europeans in the mid-1500s.

Table 8.1 shows eigenvector centralities calculated on the San Pedro sites for each 50-year period, separated by decorated (A) and undecorated (B) wares. Blank entries indicate that a site was not inhabited in that period. Looking first at the decorated wares during the period AD 1200–1250, there is a range in centrality scores with the highest being Ash Terrace and High Mesa with nearly identical scores. Ash Terrace is located in the best-watered part of the valley—where Aravaipa Creek flows into the San Pedro. High Mesa is also in a

[3] Sites are not considered tied to themselves, so $a_{ii} = 0$ for all nodes *i*.

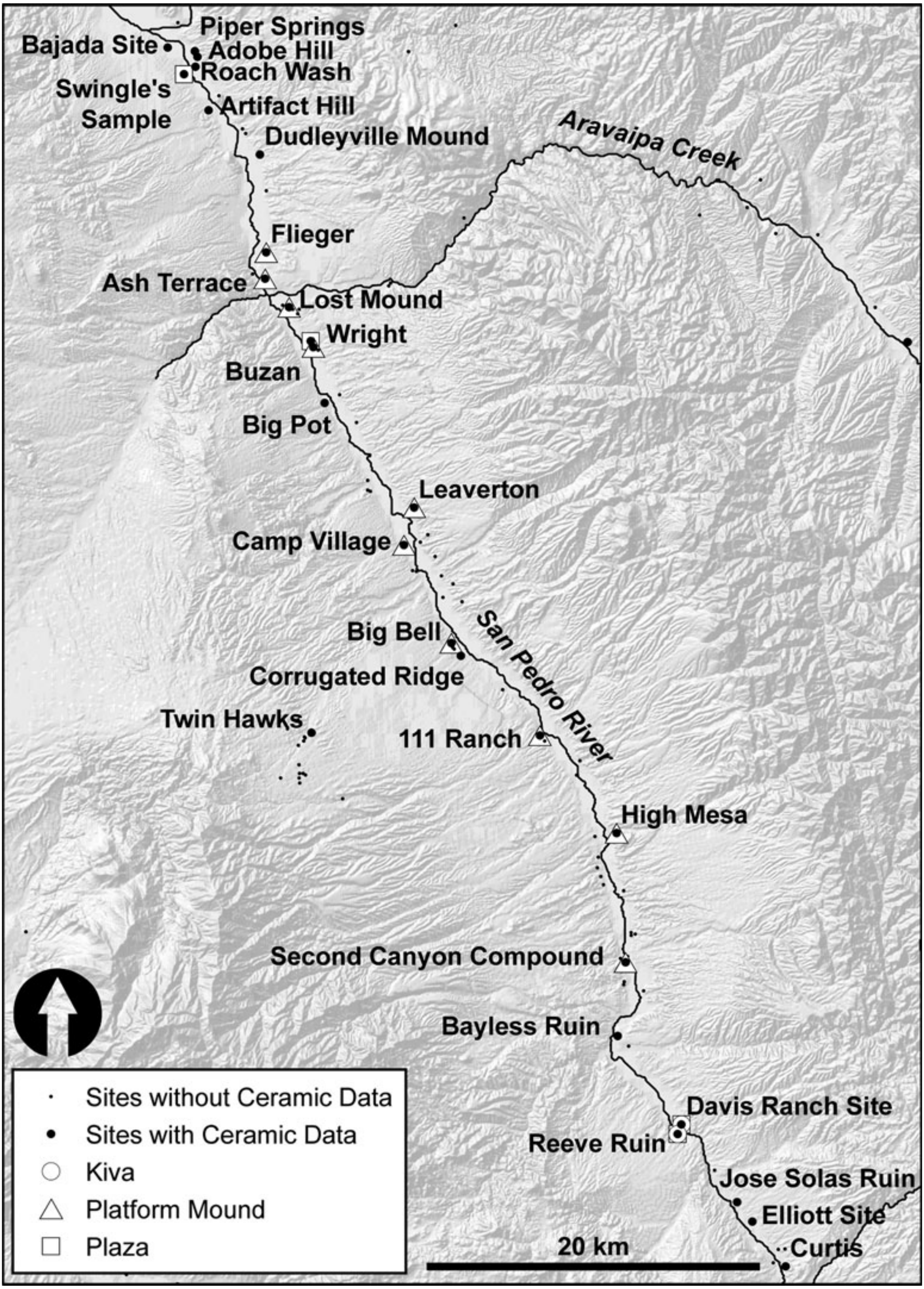


**Fig. 8.1.** Distribution of archaeological sites in the San Pedro Valley, Arizona, AD 1200–1450, showing those used in ceramic network analyses and differences in public architecture.

**Table 8.1.** Eigenvector centrality scores from dissimilarity of ceramic assemblages from San Pedro River Valley sites

A. Decorated Ceramics

| Site | AD 1200 | AD 1250 | AD 1300 | AD 1350 |
|---|---|---|---|---|
| 111 Ranch | 1.020 | 0.983 | 0.688 | |
| Adobe Hill | | | 1.025 | 1.008 |
| Artifact Hill | | 0.970 | 1.078 | |
| Ash Terrace | 1.102 | 1.155 | 1.045 | 0.987 |
| Bajada Site | | | 1.069 | 1.008 |
| Bayless Ruin | 1.084 | 0.987 | 1.062 | |
| Big Bell | 1.091 | 0.654 | 0.862 | 0.935 |
| Big Pot | 1.040 | | | |
| Buzan | 0.919 | 1.081 | | |
| Camp Village | 1.043 | 0.974 | 0.671 | |
| Curtis | | | 1.078 | 0.977 |
| Davis Ranch Site | | 1.077 | 1.073 | 1.016 |
| Dudleyville Mound | | 0.706 | 1.028 | 1.009 |
| Elliott Site | | | 1.066 | 1.020 |
| Flieger | 0.995 | 1.097 | 1.055 | 1.006 |
| High Mesa | 1.098 | 1.094 | 0.955 | |
| Jose Solas Ruin | 1.043 | 0.954 | 1.052 | 1.015 |
| Leaverton | | 0.969 | 1.032 | 0.961 |
| Lost Mound | 0.526 | 0.997 | 0.944 | |
| Piper Springs | | | 1.064 | 1.020 |
| Reeve Ruin | | | 1.044 | 1.008 |
| Roach Wash | | 1.156 | 1.081 | |
| Second Canyon | | | 0.756 | 1.006 |
| Swingles Sample | | | 1.060 | 1.018 |
| Twin Hawks | 0.898 | | | |
| Wright | | | 1.039 | 1.006 |
| **Max** | **1.102** | **1.156** | **1.081** | **1.020** |
| **Min** | **0.526** | **0.654** | **0.671** | **0.935** |
| **Range** | **0.576** | **0.502** | **0.410** | **0.085** |

*Note*: Scores at each period are normalized so that the sum of squared scores equals the number of sites.

B. Undecorated Ceramics (plain, red-slipped, textured)

| Site | AD 1200 | AD 1250 | AD 1300 | AD 1350 |
|---|---|---|---|---|
| 111 Ranch | 0.866 | 0.835 | 0.743 | |
| Adobe Hill | | | 1.063 | 1.041 |
| Artifact Hill | | 1.082 | 1.086 | |
| Ash Terrace | 1.057 | 1.017 | 0.917 | 0.948 |
| Bajada Site | | | 0.977 | 0.940 |
| Bayless Ruin | 1.059 | 1.028 | 1.032 | |
| Big Bell | 0.693 | 0.681 | 0.647 | 0.630 |
| Big Pot | 1.086 | | | |
| Buzan | 1.094 | 1.080 | | |
| Camp Village | 1.014 | 0.960 | 0.839 | |
| Corrugated Ridge | 0.765 | | | |
| Curtis | | | 1.062 | 1.044 |
| Davis Ranch Site | | 1.016 | 1.072 | 1.023 |

| | | | | |
|---|---|---|---|---|
| Dudleyville Mound | | 1.050 | 1.079 | 1.051 |
| Elliott Site | | | 1.079 | 1.051 |
| Flieger | 1.057 | 1.007 | 0.903 | 0.936 |
| High Mesa | 1.086 | 1.091 | 1.071 | |
| Jose Solas Ruin | 1.027 | 1.019 | 1.054 | 1.043 |
| Leaverton | | 1.082 | 1.045 | 1.017 |
| Lost Mound | 1.026 | 0.922 | 0.797 | |
| Piper Springs | | | 1.049 | 1.028 |
| Reeve Ruin | | | 1.054 | 1.041 |
| Roach Wash | | 1.045 | 1.079 | |
| Second Canyon Compound | | | 1.019 | 1.026 |
| Swingles Sample | | | 1.088 | 1.053 |
| Twin Hawks | 1.066 | | | |
| Wright | | | 1.074 | 1.046 |
| **Max** | **1.094** | **1.091** | **1.088** | **1.053** |
| **Min** | **0.693** | **0.681** | **0.647** | **0.630** |
| **Range** | **0.401** | **0.409** | **0.441** | **0.423** |

*Note*: Scores at each period are normalized so that the sum of squared scores equals the number of sites.

well-watered area due to the proximity of a large side drainage. Twin Hawks, the only non-riverine site in the sample, has one of the lowest centrality scores. These results suggest that network centrality is related to riverine agricultural potential in the San Pedro during this time period.

Ash Terrace remains central in the following period (AD 1250–1300), which was the first period of migration into the valley. Nearby Flieger Ruin, the largest Classic period site in the valley, reaches High Mesa in centrality during this interval and approaches the level of centrality of Ash Terrace. Flieger and Ash Terrace remained occupied throughout the following periods, suggesting the importance of first-comer status and early centrality in the network. Big Bell, located almost exactly in the middle of the linear distribution of villages, has the lowest centrality score between AD 1250–1300, illustrating that spatial and social centrality do not necessarily correspond.

In the following period (AD 1300–1350), as migration into the valley continued, the greatest number of sites was occupied. The two most well-known migrant enclaves, Reeve Ruin and the Davis Ranch site, as well as sites in the vicinity with probable migrant components (i.e. Curtis, Elliott, Bayless Ranch Ruin, Jose Solas Ruin) exceed or rival the centrality scores of first-comer villages such as Flieger and Ash Terrace, with all in the group of sites with above average centrality. We think that this is related to the fact that the migrants became producers of highly valued decorated ceramics called Salado polychromes, and, through exchange of these vessels, their villages established connections with earlier 'well-connected' local sites. The migrant position in the San Pedro social network was enhanced by their central role in the production and distribution of these decorated ceramics.

In the last period for which we have a reasonable sample for calculating network statistics, AD 1350–1400, there is a reduction in the number of villages (seven villages from the previous period become unoccupied). During this period the range of centrality scores narrows considerably (range = 0.09 compared to 0.58 in the first period) and all settlements appear to be roughly equally central within the network. We attribute this shift to the wider production of polychrome ceramics in more villages, and the erosion of boundaries between local and immigrant villages, both in terms of distribution and consumption patterns related to decorated ceramics. Petrographic data indicate that production is still localized at a few villages (Lyons 2012).

In comparison to the decorated ceramics, the undecorated ceramics in the San Pedro show greater consistency in the ranges of centrality scores through time (Table 8.1B). First-comer villages like Ash Terrace and Flieger show decreases in centrality over time, while migrant villages such as Davis Ranch tend to start out, and remain, relatively high. Two of the least central villages are again those spatially in the middle of the drainage—Big Bell and 111 Ranch. The differences between results for decorated and undecorated ceramics argue for keeping these two categories distinct. They show different patterns in centrality, commensurate with different roles for various sites in flows of information and goods, and different communities of practice associated with the production, use, and consumption of ceramic vessels.

## 8.6 CASE STUDY 2: THE TONTO BASIN

Our second case study comes from the Tonto Basin. Data from this basin are derived from a variety of projects, including massive excavations by several academic institutions and contract companies as part of the reconstruction of the Roosevelt Dam in the 1980s and subsequent road-widening projects (see Clark 2001; Rice 1998 for a summary). The Tonto Basin projects cumulatively contribute over one million ceramics to our database. Unlike the San Pedro River Valley example, analyses were conducted by different laboratories with different protocols. As noted earlier, however, the use of wares as a basis for comparison should result in greater consistency than would the use of types, particularly for the decorated wares. Also in contrast to the San Pedro, the Tonto Basin includes more than one drainage, and multiple upland and riverine sites (Fig. 8.2). In further contrast to the San Pedro Valley, evidence for migration is largely in the pre-AD 1300 period. Our analyses of the Tonto Basin data also include sites smaller than thirteen rooms (whereas all of the San Pedro sites were larger than twelve rooms).

Table 8.2 shows eigenvector centrality scores from the Tonto Basin sites (decorated only). The first trend is that there are wide ranges in centrality scores for all periods—i.e. some of the centrality scores are quite low. This

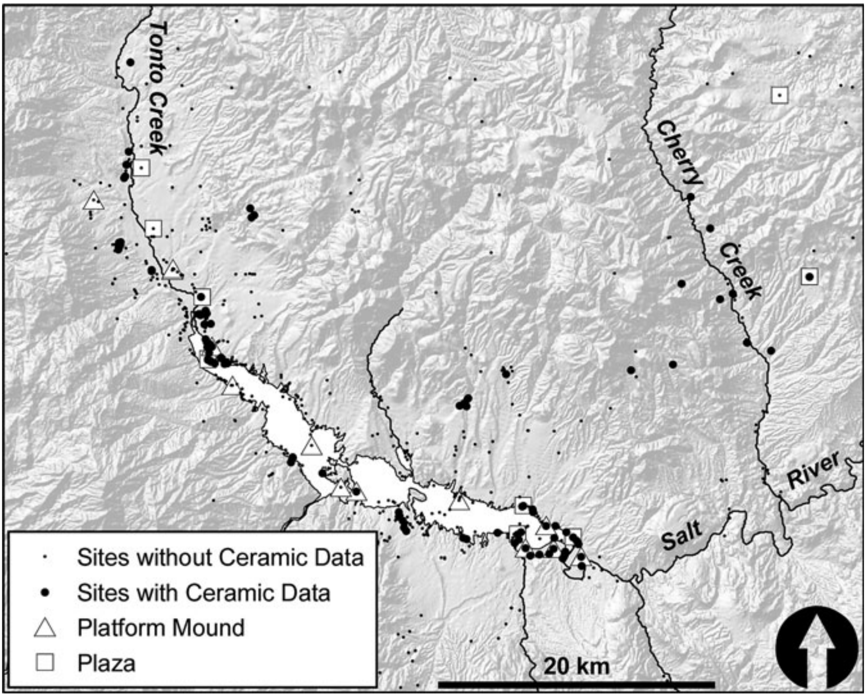


**Fig. 8.2.** Distribution of archaeological sites in the Tonto Basin, Arizona, AD 1200–1450, showing those used in ceramic network analyses and differences in public architecture.

suggests much greater diversity throughout most of the sequence. During the earliest (AD 1200–1250) period, the highest centralities are not at the largest sites—many of the smaller sites are as central as larger villages.

During the period of most intensive migration (AD 1250–1300) there is a widening in the range of centrality scores, from 0.77 to 1.03. Seven of the ten lowest centrality scores are for northern upland sites. The number of sites declines dramatically in the next period, and upland sites tend to fare poorly. For example, Cherry Creek Mound's score declines dramatically before it was depopulated. Unlike the pattern in the San Pedro Valley, high centrality in the early period does not necessarily lead to persistence, especially for upland sites. Even riverine sites show a variety of outcomes. For example, there are those with consistently high centrality (e.g. Schoolhouse Point Mound or Pinto Point Mound), while others gain prominence (e.g. Pillar Mound). Whether a site has public architecture or not also does not seem to be a major factor in high or low centrality.

Until now we have used global eigenvector centrality scores to look at changes in social networks. Looking at network topology or structure through

**Table 8.2.** Eigenvector centrality scores from dissimilarity of ceramic assemblages from Tonto Basin sites (decorated only)

| Site | AD 1200 | AD 1250 | AD 1300 | AD 1350 |
|---|---|---|---|---|
| Armer Gulch Ruin | | 0.326 | 0.439 | 0.767 |
| AZ C:1:37 | | | 0.834 | |
| AZ U:3:121 | 0.472 | 0.462 | | |
| AZ U:3:128 | 1.147 | 1.150 | 1.268 | 1.153 |
| AZ U:3:198 | | 0.794 | | |
| AZ U:3:199 | | 1.189 | | |
| AZ U:3:204 | 0.382 | 0.378 | | |
| AZ U:3:214 | 1.153 | 1.149 | | |
| AZ U:4:007 | 0.787 | 0.954 | | |
| AZ U:4:008 | 1.095 | 0.937 | | |
| AZ U:4:009 | 1.073 | 1.101 | 1.227 | 1.157 |
| AZ U:4:012 | 1.131 | 0.777 | | |
| AZ U:4:029 | 1.109 | 1.209 | | |
| AZ U:4:032 | 1.119 | 1.124 | | |
| AZ U:4:035 | 1.139 | 1.118 | | |
| AZ U:4:047 | 1.093 | 0.573 | | |
| AZ U:4:048 | | 0.269 | | |
| AZ U:4:075 | 0.927 | 1.158 | | |
| AZ U:4:077 | 1.110 | 1.169 | | |
| AZ U:4:097 | | 0.269 | 1.040 | |
| AZ U:4:099 | | | 1.040 | |
| AZ U:8:052 | 1.095 | 1.047 | | |
| AZ U:8:078 | 1.095 | 1.047 | | |
| AZ U:8:152 | 1.095 | 1.159 | | |
| AZ U:8:187 | 0.774 | 0.485 | | |
| AZ U:8:318 | | | 1.147 | 1.153 |
| AZ U:8:400 | 0.905 | 0.934 | | |
| AZ U:8:454 | | 0.864 | | |
| AZ U:8:514 | | | 1.049 | |
| AZ U:8:515 | | 0.343 | | |
| AZ U:8:531 | | 0.980 | | |
| AZ U:8:589 | 0.607 | 0.524 | | |
| AZ V:1:167 | | | 0.588 | |
| AZ V:1:185 | 1.120 | 1.130 | | |
| AZ V:5:103 | 1.070 | 0.977 | | |
| AZ V:5:105 | 1.095 | 1.047 | | |
| AZ V:5:119 | 1.131 | 1.196 | | |
| AZ V:5:121 | 1.112 | 0.924 | | |
| AZ V:5:125 | 1.108 | 1.108 | | |
| AZ V:5:130 | 1.154 | 1.133 | | |
| AZ V:5:141 | 1.143 | 1.179 | | |
| Bass Point Mound | 1.075 | 1.138 | | |
| Behrend Capture | | 1.157 | 1.114 | |
| Cherry Creek Mound | 1.005 | 1.013 | 0.814 | 0.071 |
| Cline Terrace Mound Monster Ruin | | | 0.668 | 1.155 |
| Cooper Forks Cliff Dwelling | | 0.415 | 0.612 | |
| Corner Creek Ruin | | 1.106 | 1.192 | |
| Granary Row | 0.852 | 1.194 | | |

| | | | | |
|---|---|---|---|---|
| Granite Basin | | | 0.745 | 0.401 |
| Griffen Wash Complex | 0.750 | 1.057 | | |
| Indian Point Complex | 1.067 | 1.131 | 1.132 | 1.156 |
| Knife Ridge Site | 0.877 | 0.902 | | |
| Las Manos | 1.095 | 1.047 | | |
| Las Tortugas | 1.074 | 1.162 | | |
| Los Hermanos | 1.127 | 1.203 | | |
| Meddler Point Complex | 0.879 | 1.091 | | |
| Meddler Point Mound | 0.850 | 1.174 | | |
| Middle of the Road Site | 1.123 | 1.178 | | |
| Pillar Mound Livingston Mound | 0.682 | 0.991 | | |
| Pinto Point Mound | 1.070 | 1.210 | 1.206 | |
| Porcupine Site | 0.821 | 1.048 | | |
| Pottery Point Ruin | | | 0.867 | |
| Prickly Saguaro | 1.095 | 1.047 | | |
| Pyramid Point Complex | 0.705 | 0.963 | | |
| Roosevelt 913 | 0.909 | 1.066 | | |
| Saguaro Muerto | | 1.175 | | |
| Sand Dune Site | 1.039 | 0.993 | | |
| Schoolhouse Point Mesa Complex | 1.137 | 1.206 | | |
| Schoolhouse Point Mound | 1.017 | 1.190 | 1.269 | 1.141 |
| Site AA | | 0.195 | | |
| Tonto Cliff Dwellings | | 1.226 | 1.257 | 1.130 |
| Upper Coon Creek | | | 0.835 | |
| Vista del Puerto | 0.590 | 0.901 | | |
| **Max** | **1.154** | **1.226** | **1.269** | **1.157** |
| **Min** | **0.382** | **0.195** | **0.439** | **0.071** |
| **Range** | **0.771** | **1.032** | **0.830** | **1.085** |

*Note*: Scores at each period are normalized so that the sum of squared scores equals the number of sites.

network graphs can be useful but as noted earlier, in many cases legibility of the graphs requires binarization of the data. The decision on what dissimilarity cutoff(s) to use to binarize is an empirical question that we have grappled with for our analyses; i.e. how dissimilar/similar should sites be to warrant a tie? When we have sites that span different time periods and the dissimilarity indices vary from one time period to the next, a relative cutoff (e.g. the 25 per cent most similar) may vary a good deal over time, so that the same dissimilarity may be indicated by a present tie in one period and an absent tie in the next. In addition, when we wish to compare areas, a relatively high score in one area may not be one in another. These considerations argue for use of an absolute cutoff. Absolute in this sense means that we do not rely on the density of examples in a histogram of dissimilarity scores in a particular area or time period to suggest a cutoff, but rather employ a consistent cutoff of the actual dissimilarity scores themselves; i.e. $D_{ij} \leq 0.25$, or $D_{ij} \leq 0.10$, in all areas or periods.

We illustrate two examples of network diagrams from the Tonto Basin using the $D_{ij} \leq 0.25$ absolute cutoff for the binarization of ties, one showing

ties from AD 1250–1300 (Fig. 8.3) and the other from AD 1300–1350 (Fig. 8.4). The size of nodes reflects eigenvector centrality (from the un-binarized dissimilarity data). The density, or the proportion of possible ties that are present, varies slightly between the two graphs, from 0.17 to 0.16. Although the total number of sites considered differs between the two periods, similar proportions of ties are judged present in both.

The network graph for the AD 1250–1300 interval shows several subgroups (Fig. 8.3). Most prominent is one dense cluster in the centre of the graph, with another set of various less central sites connected to relatively few members of that cluster. Sites in the northern upland areas are less well represented in the main cluster. Perhaps most importantly, there are very few sites with platform mounds outside the densely connected subgroup in the centre of the graph (Pyramid Point Mound and Cherry Creek Mound, an upland mound site, are the exceptions). Saguaro Muerto and Griffin Wash are both immigrant enclaves that are important in connecting the dense centre cluster with a somewhat less dense subgroup in the upper-left portion of the graph. A third immigrant enclave, AZ U:8:454, has few ties although it is located in one of the most populated portions of the Tonto Basin.

Comparing Figs. 8.3 and 8.4, representing two consecutive time slices, it is apparent that the social networks in the Tonto Basin were considerably transformed around AD 1300. Not only is the number of sites significantly reduced, but the clusters are reconfigured (under the binary conception of the ties being used in these graphs). There is a growing distinction between northern upland and riverine sites as seen by the two separate clusters. The few upland sites that persisted during this interval form a subgroup of seven sites with low centrality scores including Cherry Creek Mound and Cooper Forks Cliff Dwelling. Overall, observed changes are commensurate with a general trend of population aggregation into fewer sites.

## 8.7 STABILITY OF CENTRALITY MEASURES

The stability or reliability of network measures warrants further discussion. Different measures of centrality may have varying degrees of stability given different data sets and sampling criteria. One investigation of Bonacich's 1972 eigenvector centrality, the measure used in this chapter, indicated high variability in the measure when nodes are sampled, as the dependence of one node's centrality on all the other nodes in the network can make it highly vulnerable to omission of relatively few actors (Costenbader and Valente 2003). In the San Pedro case, we are very confident that all the nodes within the drainage have been identified, but less so in the case of the Tonto Basin.

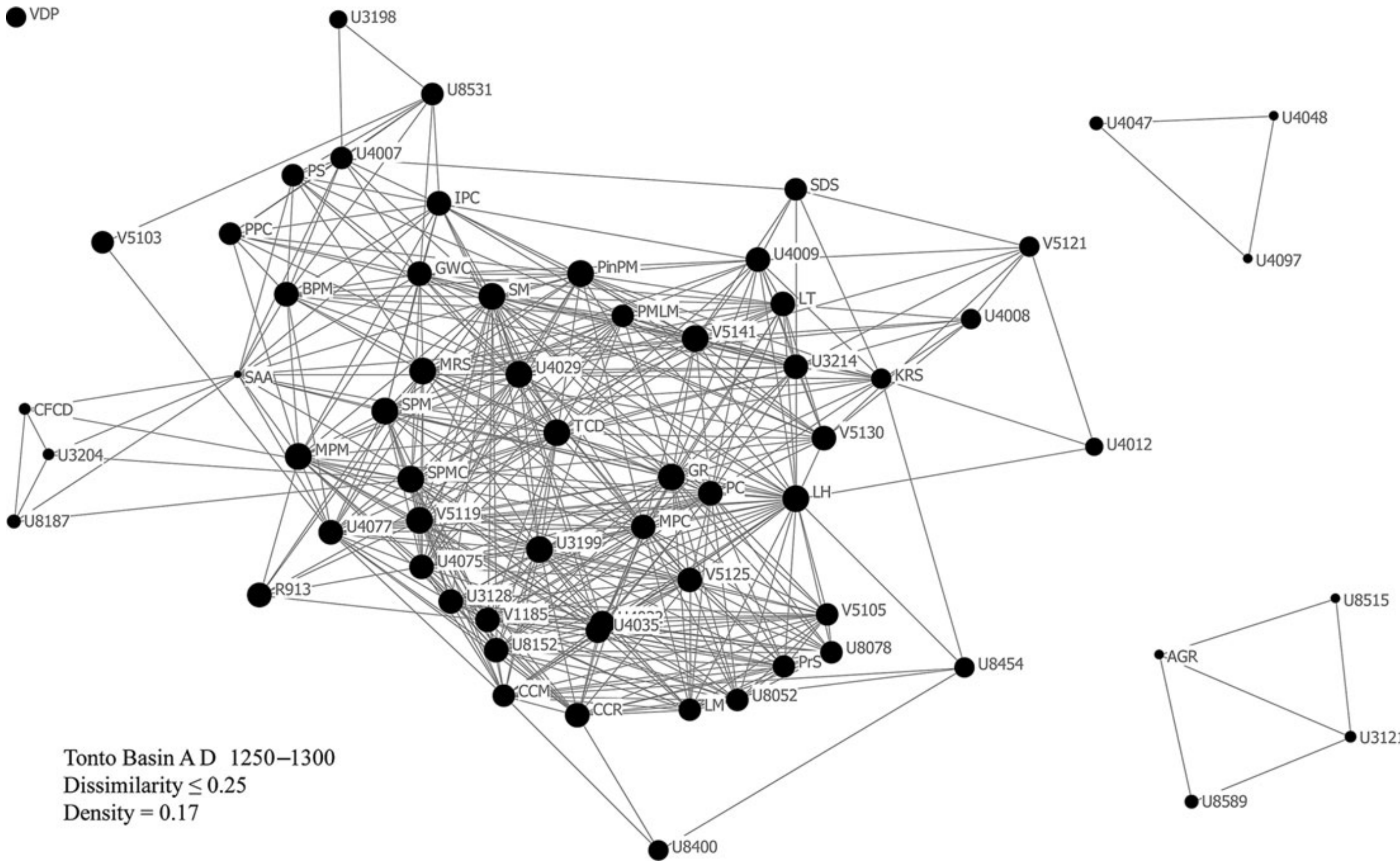


**Fig. 8.3.** Network of Tonto Basin sites, AD 1250–1300, based on dissimilarity index <= 0.25, density = 0.17. Size of nodes is based on eigenvector centrality from un-binarized dissimilarity data.

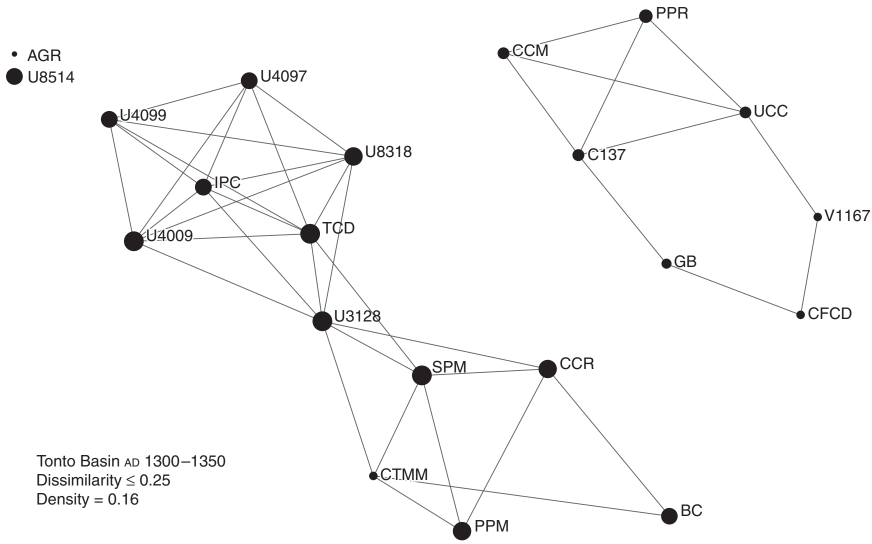


**Fig. 8.4.** Network of Tonto basin sites, AD 1300–1350, based on dissimilarity index <= 0.25, density = 0.16. Size of nodes is based on eigenvector centrality from unbinarized dissimilarity data.

Our earlier discussion of the centrality scores was descriptive, but of course these scores also can be viewed as statistics in which there is inherent sampling variability. Space does not permit a full discussion here, but we have investigated sampling variability in these scores using resampling (e.g. bootstrap) methods (e.g. Ringrose 1992). To assess sampling variability, we created a large number of bootstrap data sets, using the San Pedro data for two time periods (AD 1200–1250 and 1300–1350). To generate a bootstrap data set, we resampled (with replacement) the observed number of sherds from the observed ware distribution for each site. Each bootstrap data set was then analysed in the same way as the actual data set: apportioned by time period, with ceramic dissimilarity indices and eigenvector centrality scores calculated for each period. The distribution of these measures across the many bootstrap data sets allows us to estimate the sampling variability in the centrality scores, or at least that variability resulting from the original sampling effort at each site.

Briefly, this analysis suggested that the resolution of the data is not sufficient to distinguish between quite similar centrality scores, as small differences in the centrality scores are swamped by sampling variability. Small differences in scores should not be viewed as reflecting statistically discernible differences among sites. However moderate-to-large differences do seem meaningful even in light of sampling variability, so that substantive interpretation of such differences among site centrality scores appears to be accurate; such differences in scores most likely reflect real differences among the sites rather than

statistical noise. Our earlier discussion of differences in centrality measures focuses on these larger scale differences and we would caution against over-interpretation of the scores in this light. We would also recommend that such a bootstrapping approach be incorporated into other archaeological applications of centrality scores (eigenvector or any other).

## 8.8 CONCLUSIONS

Our major conclusions include the finding that networks changed substantially over time and with migration, but that this played out differently in our two case studies. In the San Pedro Valley, migrants established themselves relatively quickly as quite central in social networks, even as central as some of the first-comer villages. This was true for both the decorated and undecorated ceramic networks. For the first-comer villages, those in the best agricultural areas maintained high centrality, while others outside these prime areas did not (despite the latter being spatially central in the riverine system). In the Tonto Basin, there was greater diversity in centrality scores with some of the most central sites located in the uplands, possibly as links to other communities lying outside of the basin. The graphs of network topology showed that despite sharing high centralities, the upland sites formed a somewhat distinct subgroup separate from the riverine platform mound sites and associated settlements. In contrast to the San Pedro case study, Tonto Basin sites that were central early on did not remain central, no matter where they were located. Centrality does not guarantee persistence and, in fact, there was a much more punctuated history for the Tonto Basin.

If SNA results were merely consistent with much of what was already known independently from previous research in the San Pedro Valley (e.g. Clark and Lyons 2012), where considerable archaeological work has been conducted, we would have considered the analyses useful. But in addition, we also wanted to show that we learned something new by applying SNA—especially as we start to move into the analysis of less well-studied areas. Quantification of centrality and visualization of ties based on ceramic assemblage data permit insights and interpretations that are not possible with informal inspection of assemblages, or even analyses that are based solely on the calculation of dissimilarity scores. That is, our discussion of the case studies above is not just a formalized version of what one would intuit from looking at the original ceramic data. Rather it provides different perspectives on those data. As it happens, continuities exist between the insights yielded by this perspective and what researchers have already learned about these areas, and those continuities encourage us to continue developing this perspective.

But the case studies also show that SNA offers the chance to extend conventional analyses in exciting ways.

Our ongoing work seeks to include more formal descriptions of change over time, and relate these descriptions to current understanding of the history of migrations in the southern US Southwest. For example, are migrants in different valleys more similar to each other than to their non-migrant neighbours and hosts within their own valley? Now that we have the full SWSN database constructed, we can begin exploring the potential of macro-regional network analyses in conjunction with geographic analyses. Network analyses at larger geographical scales will allow us to look at where emergent networks formed, the diameter of networks, and the extent to which distance dictates similarity in distributions of material culture. These analyses present the opportunity to take advantage of the vast amount of archaeological data that has been collected in the Southwest and to bring us closer to an interdisciplinary realization of the potential of social network analysis for understanding the past.

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# 9

# Social Networks, Path Dependence, and the Rise of Ethnic Groups in pre-Roman Italy

*Emma Blake*

## 9.1 INTRODUCTION

The Roman conquest of Italy was facilitated by the disunity of the peninsula's inhabitants, divided into myriad autonomous regional groups that failed to mount an effective unified resistance. Characterizing these groups—variously described as political, ethnic, tribal, linguistic, and cultural—remains an ongoing research question, made more difficult by the paucity of native texts in this particular case, and by the polyvalent and mutable foundations of group identities more generally. In the popular imagination Italy's regionalism is seen as endemic, attributable to the peninsula's varied topography and natural internal boundaries. Yet if we go back far enough, to the Middle and Late Bronze Ages (hereafter, MBA and LBA, 1700–1050 BCE),[1] the peninsula is characterized by extreme uniformity in material culture. It is only with the transition from the Final Bronze Age to the Iron Age around the turn of the first millennium BCE that regionally inflected material-culture patterning becomes apparent, suggesting the emergence of regional groupings. Proposed dates for the inception of full-blown regional identities therefore span most of the first millennium BCE, up until the Roman conquest.

Explanations for the formation of these regional groups have followed the scholarly fashions in shifting from primordialist to instrumentalist perspectives in recent decades, and the current emphasis is on identity formation either as a response to outside pressures of various types (first from Greek

[1] In Italy the Late Bronze Age is divided into the Recent Bronze Age (1350–1200 BCE), corresponding to the Subapennine period, and the Final Bronze Age (1200–1050 BCE), corresponding to the Protovillanovan period.

colonists and then from the Roman conquerors) (e.g. Bradley 2000 for the Umbrians; Dench 1995 for the Samnites), or as a means of managing resources within a territory (e.g. Peroni 1979: 15; Bietti Sestieri 1997: 378; 2005: 20). In this chapter I use the evidence from west-central Italy, home to two of the peninsula's strongest regional groups before the rise of Rome, the Etruscans and the Latins, to demonstrate that the regional groups of the first millennium BCE may be traced from earlier than previously thought, and were the outcome of intra-regional social networks in place by the Final Bronze Age or earlier. As with all human groups, the manner in which Italy's peoples communicated and cooperated with each other and with their neighbours had a profound effect on their survival. These patterns of interaction, visible in west-central Italy in the Recent and Final Bronze Ages (RBA and FBA), preceded the peoples' crystallization into self-identified regional groups. In what may be termed an interactionist theory of identity formation, these habitual networks engendered the regional groups that followed. Thus, in what amounts to path dependence, the character of these regional networks determined the subsequent character of the groupings themselves: cohesive regional networks preceded strong regional groups, even ethnic groups, and regions without networks or with only weakly connected ones did not. So in the case of the Etruscans, a cohesive 'proto-Etruscan' social network was the foundation on which subsequent ethnic identity was built, while with less evidence the same pattern is suggested for the Latins.

How does one detect these networks, given that the local material culture in the Bronze Age is so uniform geographically? This chapter proposes that these networks are visible archaeologically in the distribution of certain categories of easily traceable foreign objects, which will have circulated along the paths of the hypothesized networks, moving between sites (nodes). I begin by suggesting that social networks may be a better way to identify incipient regional groups than expressive actions of identity are, then discuss the methods for detecting these social networks through artefact distributions, and conclude with the west-central Italy case study.

## 9.2 ETHNICITY AND SOCIAL NETWORKS

Regional identity formation may be understood through the framework of ethnicity, on which there is extensive scholarship. There are few scholars who would suggest we can get at ethnicity through archaeological remains alone. Drawing on ethnographic examples, Jonathan Hall (1997) has stated that an isomorphic relationship between bounded material-culture assemblages and ethnic groups is far from a given, and that the mobilization of material culture in strategies of ethnic expression may stop and start over time. This makes it

difficult for archaeologists to know if changes in material-culture patterning denote changes in identity groups or are simply changed expressions of otherwise established groups. Hall winds up stating that, 'the obvious conclusion to be drawn—unpalatable perhaps to some—is that the entire enterprise has little chances of success in situations where the only evidence to hand is archaeological' (Hall 1997: 142). From Hall's perspective, the emergence of differentiated material culture in the regions where we know later there were ethnic groups need not constitute the moment of ethnogenesis. Instead the changed material culture may signify some other behavioural shift, one that is occurring within a group that has long since been ethnically defined, or which is not yet ethnically defined.

Other scholars have focused on common practices rather than objects as indices of early ethnicities. Kamp and Yoffee suggested that we approach ethnicity through particular behaviours instead of material culture distributions (1980: 226). Similarly, for Jones (1997), ethnicity emerges from shared dispositions and practices (Bourdieu's *habitus*) that give authenticity and credibility to ethnic belonging, despite its tactical component: her framework is meant to bridge the primordialist/instrumentalist divide (1997: 128), and to open a way for archaeologists to use material culture, as remnants of practices, to study ethnicity. Morgan (2009), too, advocates identifying norms of conduct as ethnically inflected. All of these approaches are nonetheless difficult to apply without supporting textual evidence. As Whittaker baldly stated, 'archaeology cannot dig up ethnicity and it is time the debate shifted to the domain of social history' (2009: 202).

Given that the two standard archaeological markers of regional groupings, discontinuous distributions of material culture and variations in habitual practices, are difficult to read in many cases, I propose an alternative approach. A prerequisite of a regional group, indeed of most social groups, is communication between members. Rather than seeking material emblems of a regional identity, or traces of shared practices, what about seeking material traces of that communication? Communication between group members entails contact. We may expect that, given the opportunity, members of a group will interact more often with other members of their group than with people external to their group. These interactions between members of a group may take any number of forms, from face-to-face visits to exchanges of gifts to business transactions to acts of domination and violence, but the important thing here is that they occur. Each interaction constitutes a tie linking two members of a group. The web of interactions or ties between members of the group forms a structure or network linking people together. This shift in emphasis to interaction and away from what may be called 'identity habits' (both materials and practices) may lead to more reliable identifications of past groups. Intra-group communication is essential for group maintenance, whereas expressions of identity are contingent, mutable, and not always necessary. Likewise, some emblems and practices can be shared beyond the group, and it

is not always clear which emblems and practices are group-specific. An interactionist model bypasses some of these ambiguities.

Most, indeed almost all of the interactions in prehistory are lost to us. But some of these interactions may leave traces in the archaeological record. In fact, many of the material object distributions that we interpret in terms of expressions of affinity or social status or economy may be reconceived as traces of networks. In other words, I propose that regional groups may be visible in the traces of their communication networks such that one would expect fewer exchanges of objects occurring between members of different groups than among members of the same one. Thus one method for spotting regional groupings in prehistory may be to look for density variation in the distribution of some categories of material culture.

If one perceives of ethnicity as a particularly intense and tight-knit form of regional grouping, one may expect that ethnic groups would maintain relatively cohesive social networks. But we can go a step further and suggest that cohesive social networks may be a *prerequisite* for ethnic group formation. Recent emphases on ethnicity as an ongoing process underestimate the achievement of creating an ethnic group from what was no more than a regional group: an ethnic group represents an investment already made, no matter how much more is required to maintain these dynamic and mutable entities. This makes the motives and triggers for that investment worthy of close examination, and pushes the discussion back towards ethnogenesis and the roots of ethnic groups. Morgan rightly urges us 'to re-examine past assumptions about the complex of relations from which individual communities were constituted' (2009: 25). Even if one takes the instrumentalist view of ethnicity developed by Barth (1969), Patterson (1975), and others, for an ethnicity to work it cannot be fabricated out of nothing: it is a new iteration of an earlier weaker grouping, often locality-based. This means that the evidence for networks of interaction in areas that later form the territories of regional groups is valuable, demonstrating a correlation not between ethnicity and active material culture expression, but rather between ethnicity and community connectedness or solidarity. This last criterion, one that Anthony Smith (1999) gives for ethnicity, is not unique to ethnic groups and so is considered a 'weak' ethnic marker, compared to a common name, territory, and language. But if one assesses a region's degree of connectedness, one may come some way to predicting the emergence of an ethnic group.

At issue here is path dependence, which in its loosest form is the notion that earlier conditions and events affect the course of subsequent ones. As this broad approach amounts to little more than the old adage that 'history matters', some scholars advocate a narrower definition that offers greater analytical payback. Margaret Levi (1997: 28) suggests, 'Path dependence has to mean, if it is to mean anything, that once a country or region has started down a track, the costs of reversal are very high. There will be other choice points, but the entrenchments

of certain institutional arrangements obstruct an easy reversal of the initial choice.' Pierson reformulates this as a case of increasing returns, or a positive feedback loop: if one way of doing things is going well, the group is likely to continue doing things in that manner (Pierson 2000: 252). This description may be apt for the regional networks-turned-ethnic-groups of early Italy. We can imagine that regional-scale relationships, once established, would continue in much the same manner over long periods of time, not simply because of inertia, but because there were reliable payoffs to be had from those relationships. Changing the dynamic by severing those ties and establishing new ones may not have seemed worthwhile. How does path dependence work, in concrete terms? The residents of two nearby settlements may build an enduring relationship through repeated instances of mutual aid, exchanges of gifts, successful marriages, or alliances against other groups, for example. In the absence of the third-party guarantees or rule of law that secure transactions in state-level societies, the resulting mutual trust would make it far easier to interact with each other than with communities with whom there is no shared history. Indeed, the path dependence may take a literal form: established roads linking two sites would make it preferable to visit one another instead of launching out towards another settlement. With path dependence the costs of changing course grow over time. Pierson (2000: 253) notes, 'These are processes in which sequencing is critical. Earlier events matter much more than later ones, and hence different sequences may produce different outcomes.' This point is very important when assessing the condition of the groups at the moment of the Roman conquest. The recent emphasis of pushing ethnicity formation very late indeed, as a response to Roman imperialism, overlooks the incredible difficulties of changing course so far along. While clearly the threat of annihilation (whether physical, cultural, or both) would have been a good motivator to unify, old relationships, perpetuated previously with some measure of positive results, may have been hard to change.[2] Thus the presence of social networks, and their degree of cohesiveness, may have influenced the character of Italy's regional groups and their trajectories.

## 9.3 WEST-CENTRAL ITALY AND THE PROTO-ETRUSCAN AND PROTO-LATIN NETWORKS

The Etruscan and Latin peoples are ideal for testing this hypothesized link between Bronze Age networks and Iron Age identities. The historic territory of the Etruscans is delimited by the Arno River to the north and the Tiber River to the south and east. The territory benefits from fertile soils in its alluvial

[2] Ruane and Todd (2004: 225) make a similar point about the self-reinforcing nature of 'solidaristic linkages'.

plains: it is where the Apennine Mountains are at their narrowest, allowing for a much wider swathe of agricultural land extending inland from the coast than other areas of Italy outside the Po Valley. Etruria is also, in its northern zone, home to some of the richest mineral deposits in the Mediterranean. The *Colline Metallifere*, or 'Ore Mountains', had sources of copper, lead, silver and even tin. These natural advantages were deftly exploited by the region's inhabitants. In an often-told story (see Barker and Rasmussen 1998 and Haynes 2000 for overviews), beginning in the 8th century BCE and peaking *c.*700–470 BCE, the Orientalizing and Archaic periods, the peoples of the southern part of what became Etruria underwent phenomenal changes. Urbanization and a new articulation of elite identity occurred over the course of this period (Riva 2010: 6). The wealth of the Etruscan elites, their intense and fruitful interactions with Greeks and Phoenicians, their engineering technology, their complex religious beliefs and nimble adoption of writing for their own ends, their artistic heights and commercial acumen, are without equal in the central and western Mediterranean in this period. Although organized into autonomous city states, the cultural uniformity overlying the civic or micro-regional variations makes it clear that the Etruscans were a coherent and self-defining cultural group, beginning first in the southern portion of Etruria and eventually expanding north towards the Arno.

Across the Tiber River to the south, the Latins too stood out amongst looser groupings like the Volscians and the Sabines. In the first millennium BCE the Latins, like the Etruscans, were divided into city-states that were politically independent but shared a common language, religion, and myth of origin. Ancient Latium, *Latium Vetus* (as opposed to the modern region of Lazio, which covers a portion of what had been Etruscan territory) was bounded by the Tiber to the north-west, the sea to the west, the Aniene River to the north, the Apennines to the east, and extended as far south along the coast as Cape Circeo at the end of the Pontine Marshes (Cary and Scullard 1975: 31).[3] While Latium Vetus lacks the natural resources of Etruria, it contains a relatively fertile farmland, if not as rich as Campania to the south (Smith 2007: 162). Urbanization and political complexity began later in Latium than in Etruria. Bettelli (1997: 218), drawing on Pacciarelli's research, notes proto-urban settlements in Latium from 50–100 hectares in size from the 9th century BCE on, spaced regularly, so possibly controlling a territory of 100–150 km$^2$. These appear somewhat later than their counterparts in Etruria.[4] The Archaic

[3] The southern and eastern boundaries of Latin territory, separating the Latins from the Volscians on the one hand and the Sabines and other mountain peoples on the other, were not hard and fast from what the ancient sources report, and the mountain dwelling Volscians may have settled in southern Latium in the 5th century BCE until the territory was reclaimed by the Latins.

[4] Bettelli distinguishes Rome from the other Latin city states by its larger size and distance from them, suggesting that its territory was vaster as well. On the other hand Carandini (1997: 481–2) presents Rome as neither bigger than, nor distinguishable from the other proto-urban

period sees major transformations occurring in Latium, with the nucleated settlements of the Iron Age evolving into urban centres with planned layouts, civic religious structures, and specialist workshops.

Is there anything about west-central Italy in the LBA that would allow us to predict its subsequent bifurcation into two main ethnic groups (amid other smaller groupings)? The population centers were small, and social differentiation was minimal. Craft specialization was apparently limited to metalworking and a subsistence economy prevailed, with relatively few outside contacts.[5] But there are some significant changes in the LBA, including population growth and agricultural intensification, which may have established the necessary preconditions for the eventual rise in social complexity. These changes are detectable throughout much of Italy but are particularly intense in Etruria (Barker and Rasmussen 1998). In the case of the Latin peoples, in contrast to the Etruscans, the LBA predecessors have offered few if any hints of the transformations of the Archaic period. In short, the picture of west-central Italy in the Bronze Age appears indistinguishable from much of the rest of the peninsula at this time. A regional identity is thought to emerge with urbanization and state formation in the Iron Age, so that the three phenomena are treated together. But prior to the rise in social complexity, there are in fact early signs of distinctive groupings in the distributions of intrusive objects across west-central Italy.

Mycenaean pottery, amber beads of Tiryns and Allumiere type, selected bronze objects, and even donkey remains stand out in the material record as intrusive. The Aegean pottery, both imported and made on Italian soil,[6] has been found at some ninety-six sites to date on the Italian peninsula and islands. The Aegean pottery in Italy spans five centuries, with the earliest examples of Late Helladic (LH) I–II type, dating to 1600 BCE or so, and the last finds of LH IIIC type, *c.*1200–1100 BCE, and spanning most of the Italian FBA. The sherds that are most useful here are those which overlap temporally with other categories of imports, the amber and bronze objects. These belong to the LH IIIB–C periods, dating to 1300–1100 BCE. While some scholars have distinguished between LH IIIB and LH IIIC sherds at particular Italian sites, others have cautioned against false precision, as in many cases the sherds are small and worn, and the Italo-Mycenaean-ware chronology does not necessarily

centres such as Gabii and Ardea, although acknowledging that the earliest settlement at Rome does predate these other centres, going back to the MBA.

[5] The contrasts with the later Etruscans are marked enough that some scholars draw on this and the peculiarities of the Etruscan language to insist they must have been an intrusive group who settled in the region from a more developed area, possibly Anatolia (e.g. Magness 2001). Inferences have also been made from genetic studies, but these remain controversial (Achilli et al. 2007; Guimaraes et al. 2009).

[6] These are the so-called Italo-Mycenaean wares, made at sites in southern Italy and possibly Sardinia.

correspond tightly to the Aegean one (Vianello 2005: 14).[7] For these reasons I have combined in this list the findspots in west-central Italy with sherds of either LH IIIB type, LH IIIC type, or both.[8] The Tiryns and Allumiere beads date to 1150–1050 BCE, the Italian FBA.[9] They seem to have been produced at multiple locations, perhaps originating in Greece and later being made in Italy and Sardinia. Across the Italian peninsula, the beads' distribution is somewhat skewed towards the north, compared with the Aegean pottery, and Negroni Catacchio et al. (2006) suggest an entry into the Italian peninsula in the northern Adriatic, whether overland or by sea from Greece.

The bronze objects are a selection of six well-attested types that are contemporary with the Aegean LH IIIB–C pots. It is difficult to date them more precisely than that, as there remains much confusion over the RBA and FBA chronology in Italy. Just as the Aegean sherds of LH IIIB and LH IIIC are not easy to distinguish, the bronze objects' find contexts span the RBA and FBA in a confusing manner, making it safer, though less precise, to group the two periods together (see Peroni 1994 for a discussion of the RBA and FBA chronology in Italy). These objects are: the Pertosa flange hilted dagger, Variety A (Bianco Peroni 1994: 149–52);[10] Torre Castelluccia dagger, Variety A (Bianco Peroni 1994: 122–4);[11] flattened violin bow fibula with two bosses (von Eles Masi 1986: 10–11);[12] Pertosa sword (Bianco Peroni 1970: 23–7);[13] Cetona sword (Bianco Peroni 1970: 63–5);[14] and Montegiorgio sword (Bianco Peroni 1970: 57–61).[15] Finally, the early introduction of the donkey may be understood as a technological innovation of sorts whose distribution can be mapped in the manner of any other object.[16] Donkey bones are known from a handful of sites on the peninsula in the LBA (de Grossi Mazzorin 1998). Donkeys are excellent pack animals, and as such would have facilitated exchanges between regions of Italy: Brodie has argued for the Aegean that donkeys made possible long-distance overland bulk transport for the first time (Brodie 2008).

[7] Indeed, Vianello (2005: 43) proposes even broader groupings by chronological type for the Aegean sherds found in Italy, recommending simply two large categories, LH I–IIIA1 and LH IIIA2–LH IIIC.

[8] The sites are: Casale Nuovo, Luni sul Mignone, Monte Rovello, San Giovenale.

[9] The find spots of these beads in west central Italy are: Allumiere, Campo del Fico, Capannori, Colle della Mola, Elceto, Grotta Misa, Osteria dell'Osa, Panicarola, Poggio della Capanna, Ponte San Pietro, Populonia, Ripara dell'Ambra, Roman Forum, Scarceta, Villa Cavalletti.

[10] The find spots are Capitan Loreto, Castiglioncello d'Orcia, Gubbio.

[11] The find spots are Coccorano and Colle della Mola.

[12] The find spots are Cavallo Morto and Cetona.

[13] The find spots are Lago Trasimeno and Quercianella Sonnino.

[14] The find spots are Cetona and Lago Trasimeno.

[15] The find spots are Lago Trasimeno and Monte Sant'Antonio.

[16] The find spots are Luni sul Mignone, Scarceta, Sorgenti della Nova, and Torrionaccio.

This theory that the distributions of imported objects are material traces of past interactions, in this case regional interactions, is based on two premises. The first premise concerns the nature of Bronze Age trade. Given that trade was limited in Italy in this period, and given the linguistic and cultural hurdles to be overcome for foreign traders to ply their wares there, one must expect that traders coming by sea would stick to the coastal areas and overland traders likewise would not penetrate far into the peninsula. The fall-off in quantities of imports when one travels towards the interior would seem to confirm this picture. If outsiders were depositing their wares along the coasts, then when goods are found inland we can hypothesize that they reached there by local hands. The second premise is that sites with shared objects can be understood as having a tie to each other, through this localized circulation. Regardless of the mechanism by which the goods moved around in a particular area, such as one person going from settlement to settlement, or redistributive systems, or formalized exchanges between settlements, the co-presence of these objects must be the result of mutual awareness and most likely direct contact. Given the embedded nature of ancient trade, these local exchanges may be understood as the most visible measure of interactions that have otherwise left no archaeological trace. But propinquity must have played a role: sites with similar objects but hundreds of miles apart may have had no direct contact. In short, two sites sharing the same intrusive material and a short distance apart can be reasonably thought to be tied together, that is, to have a relationship. I define 'short distance apart' as 50 km, or a rigorous day's walk or manageable sail in the case of coastal sites best linked by water.[17] While many of the find spots are closer to each other than 50 km, beyond 50 km would mean more than one day's travel, which would most likely reduce the frequency of movement between two points. Thus 50 km seems like a significant threshold beyond which we can be less sure of direct contact. From all this we can posit that in areas where material exchanges were concentrated, interactions of other kinds were also concentrated.[18]

From these premises we can now look closely at the distributions in west-central Italy, to see if there is evidence of the regional groupings to come (Fig. 9.1). Thirty findspots of intrusive objects are known within a broad swathe of territory that encompasses all the zones conventionally included in

[17] This is one method of factoring in propinquity: see Blake in preparation for alternative methods.

[18] Admittedly the imprecise chronology means that the contemporaneity of some sites is in question: for example, the necropolises of Osteria dell'Osa and Villa Cavalletti extend no earlier than the FBA, whereas the Pertosa sword is thought to date to the RBA, so the sword's absence from those two sites may simply be because the sites did not exist when this sword was in circulation. However, while there may be many reasons for the absence of ties between sites, what needs explaining is the *presence* of ties.

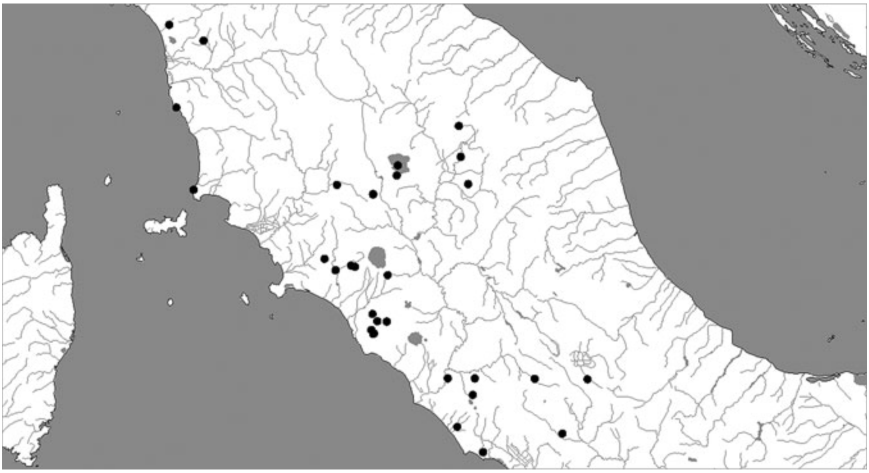

**Fig. 9.1.** Findspots in west-central Italy.

west-central Italy.[19] These findspots are primarily settlements, but there are also cemeteries and cult places.[20] The areas without findspots were not uninhabited but rather the sites located there have not yielded any intrusive objects, suggesting that they were left out of the exchanges. The map of the find spots shows two clusters, each in what is known as the heartland of these ethnic groups: south Etruria and in and around the Alban Hills. To analyse the data using social network methods I calculated the distances in kilometres between all the find spots, creating a mileage matrix in Excel. I then binarized those distances, so that sites that were 50 km or less apart from each other and had yielded the same type of object would have a direct tie (expressed in a matrix as a '1') and those either more than 50 km apart, or near each other but without the same object, would lack a tie (expressed in the matrix as a '0'). Thus, two sites that were less than 50 km apart would nevertheless not be considered to have a direct tie unless they also both had an example of the same material: one site with an amber bead and the other with a Mycenaean sherd would not have a tie. I imported the data into UCINET, the standard social network-analysis software, where the information was organized into a matrix in which the rows and columns were the findspots of all the object types. Here, I recorded a '1' in the

[19] These are based on the published lists of the objects described above: almost certainly there are newer finds that have not made it onto those lists which would expand the number of findspots, though I would not expect them to contradict the strong patterns observed below.

[20] The differences in site function are not considered here. Instead, the sites are all treated as 'activity areas' as the focus here is with the linkages between sites rather than the sites themselves. However, it is worth noting that on a peninsular-wide scale the cult sites exhibit different relationships to other sites and their surrounding territories, a point to be considered in further detail in Blake (in preparation).

cell if the site in column 1 was within 50 km of the site in row 2 (ignoring the diagonal, as Findspot 1 cannot be 50 km from itself) and both had produced the same type of object. In all other cases, a '0' was recorded in the cell. I treated the resulting data as a symmetric one-mode adjacency network. The network is symmetric because the posited ties are undirected: Site A and Site B are equally joined to each other by sharing the same object, rather than A being connected to B without B being connected to A. It is a one-mode adjacency network because all the nodes belong to the same type ('findspots'), as opposed to a network in which one compared, say, sites to pottery sherds.

The matrix's data are more easily viewed in graph form, and much information can be gained before doing any actual formal analyses (Fig. 9.2). It is immediately evident that ties between the sites of west-central Italy are sparse and that this is a disconnected network. Half the sites are isolates or linked to no more than one other site. The remaining fifteen sites make up the two clusters observed in the map. These can be labelled subgroups, one composed of eleven linked sites and the other of four linked sites. Every site in each subgroup is reachable by every other site in the subgroup, but is not connected to any sites outside its subgroup. When the findspots are plotted on a map of the region, it can be noted that the largest subgroup falls entirely within the spatial limits of what becomes Etruria, and the second largest lies within the spatial limits of what becomes Latium, with no ties between the two regions (Fig. 9.3).

Moving beyond studying the graph, we can analyse the level of cohesion using several different measures of connectivity, as a means of understanding the structure of the network of west-central Italy as a whole as well as the structure of each subgroup. Table 9.1 presents the measures of connectivity discussed below.

Density of ties is one of the key measures of cohesion: the greater the number of ties between nodes in a network, the greater the possibilities for communication and social relationships. Because the number of ties in a network is not informative unless we can compare it to the number of possible ties, density is given as a percentage of actual ties out of possible ties.[21] The clustering coefficient is a measure of the density of local 'neighbourhoods' (those nodes (here, sites) to which another node is close) within a larger network. The clustering coefficient is the average of the density of ties around each node.[22] A high clustering coefficient, therefore, suggests that within a larger network there are dense pockets of localized interaction. The Proto-Etruria subgroup is reasonably dense, with 40 per cent of all possible ties

[21] Because of the 50 km cutoff, calculating the number of possible ties, and therefore the density, of these networks is not straightforward. Indeed, in the case of the west-central Italy network the sites are too spread out for the calculation to be relevant. In the Proto-Etruria subgroup, only one site, Scarceta, is more than 50 km from five other sites in the network. The number of possible ties was adjusted and the density recalculated accordingly.

[22] The weighted clustering coefficient adjusts the average to have the larger neighbourhoods count for more.

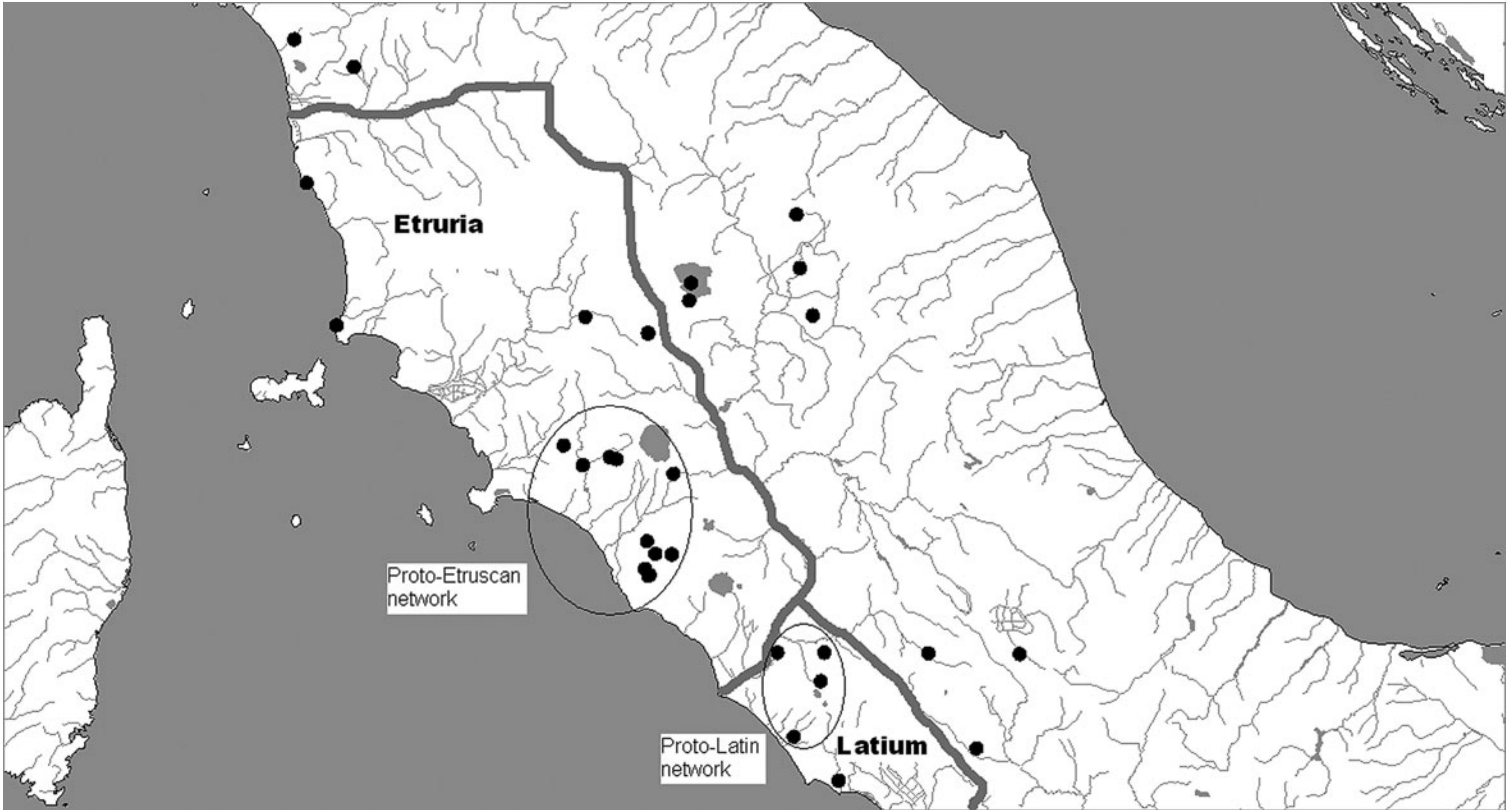


**Fig. 9.2.** Map of the findspots in west-central Italy, with the two major subgroups and later ethnic boundaries.

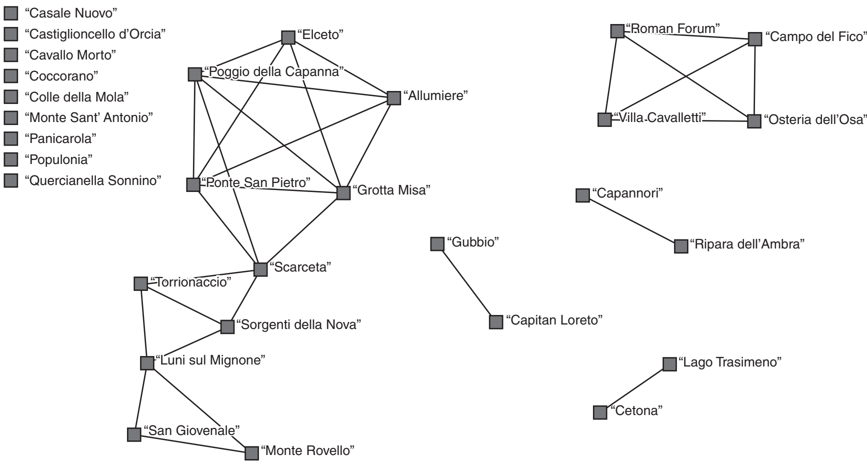


**Fig. 9.3.** Graph of the west-central Italy network.

**Table 9.1.** Measures of connectivity for the west-central Italy network and subgroups

| | Reachability | Density | Clustering coefficient | Weighted CC | Average geodesic distance | Compactness | Network centralization |
|---|---|---|---|---|---|---|---|
| WC Italy (n = 30) | No | n/a | n/a | n/a | 2.109 | 0.097 | 11.08% |
| Proto-Etruria (n = 11) | Yes | 0.4 | 0.77 | 0.727 | 2.291 | 0.605 | 14.44% |
| Proto-Latium (n = 4) | Yes | 1 | 1 | 1 | 1 | 1 | 0% |

existing. In the small Latium group all sites are connected directly to each other so the density is 100 per cent. Proto-Etruria's network has a high weighted clustering coefficient, 0.727, suggesting further subclusters. From the map in Fig. 9.1 one may detect a slight geographic bipolarity between an inland cluster in the western environs of Lake Bolsena and another cluster due south in the area around what becomes the Etruscan city state of Tarquinia, closer to the coast. In graph form, Proto-Etruria appears to divide in two subclusters, linked by the site of Scarceta, with one group showing greater cohesion than the other. Scarceta, Ponte San Pietro, Elceto, Poggio della Capanna, Grotta Misa, and Allumiere share more ties than Torrionaccio, Sorgenti della Nova, Luni sul Mignone, San Giovenale, and Monte Rovello. On closer inspection, however, it

turns out that the groupings are not geographically based, in that they cross-cut the two geographic groupings. Instead they reflect shared artefact types: the former sites are all find-sites for amber while the latter sites are find sites for donkey and Aegean pottery. The graph's bipolarity thus seems epiphenomenal, the by-product of the slim distributions of artefacts rather than a geographic bipolarity of any significance. This suggests that with a network this small, and with few imports to consider, we risk overanalysing the internal structures of the groupings, with limited information to work.

Other measures of connectivity provide a sense of how information and objects would move around the network. Average geodesic distance, that is, the average of the shortest distance between two nodes in a network, is informative. Compactness is a measure of cohesion that is based on distance between nodes rather than density.[23] The more compact a network is, that is, the shorter the average path between nodes, the quicker information can travel and the more connected it is. These measurements can only be calculated for reachable pairs so offer few insights into west-central Italy's disconnected network. At the other extreme, Proto-Latium's fully connected network, with all sites adjacent to each other, has an average geodesic distance of 1 and a compactness measure of 1. For Proto-Etruria, the average shortest path between sites, 2.043 relations, is relatively short, suggesting a compact network in which information could move quickly, and its compactness score confirms its distance-based cohesion.

Of interest also are the different roles played by individual sites within the cluster, and here the measures of the variability in nodal degrees can capture something of the range in activity of individual sites, and by extension the differences in centrality and possibly influence. The more ties a node has, the more active and presumably more powerful it can be. Network centralization measures the variability in node centrality in a network. In the Freeman Graph centralization measure, 1 = a network with total centrality (one node is connected to all others, while all other nodes are only connected to that one central node), and 0 is a totally decentralized network with no single node having more ties to other nodes than any other. The more decentralized the network, the fewer positional advantages any single node can enjoy over others (Knoke and Yang 2008: 64–5). Both for west-central Italy as a whole and in the hypothesized subgroups, decentralization prevails, with extremely low centralization scores: indeed the Proto-Latin subgroup is entirely decentralized, with all the sites in equivalent positions and directly connected. West-central Italy has a score of around 11 per cent group centrality, and Proto-Etruria is at just over 14 per cent. No sites dominate over others.

[23] Compactness is calculated by taking the harmonic mean of all the distances between nodes in a network.

## 9.4 DISCUSSION

The network analysis presented here makes certain things clear. First, there is nothing resembling a cohesive connected network unifying west-central Italy at the end of the Bronze Age. On multiple measures of cohesion the hypothetical west-central Italy network scores very low, suggesting that in spite of a common material culture, there was neither a unified trading network nor close ties between sites across the region as a whole. This absence of evidence could simply be the result of a sparse archaeological record, except for one thing: the two small but cohesive networks in place. The sites of the Proto-Etruria subgroup are all in what later becomes known as south Etruria, the area demonstrating the earliest settlement hierarchies and later the fulcrum of wealth and power of the Etruscans in the second quarter of the first millennium BCE, the period of Etruscan supremacy. The sites in the subgroup are inland, and the imports remain few in number, suggesting that the network did not grow up simply in response to the rise of long distance trade. Rather these imports make visible the ties existing between the sites. Amber beads and some bronze objects are found in what becomes northern Etruria, at the sites of Populonia, Quercianello Sonnino, Castioncello d'Orcia, and Cetona. However, there are no shared objects to link these sites together, and in some cases they are separated by distances greater than 50 km. Thus in northern Etruria in the Recent and Final Bronze Ages there is nothing to indicate the regionalism of the subsequent period, whereas southern Etruria is already by this stage demonstrating the social cohesion that will flourish later. As the Bronze Age sites do not survive the transition to the Iron Age, this network is not a predictor of the political structure to come: none of the sites in the Proto-Etruria subgroup, with the exception of Luni sul Mignone, carry on into Etruscan times. Rather the network is simply indicative of a presence on this soil of peoples interacting closely enough that they would eventually come to share a common identity.

The case for a Proto-Latin subgroup is weakened by the fact that we are dependent on the distribution of just one shared material, amber beads, to demonstrate relationships. Without supporting evidence of ties the identification of a network remains tentative. Nonetheless, the evidence we do have fits the proposed pattern well: the sites in the Proto-Latium subgroup are located in the heartland of the subsequent Latin peoples, and among them is the most important future town of all, Rome. Although this cluster is very small, that it is fully connected is notable as well. As with the Proto-Etruria subgroup we can argue that a tradition of regional cohesion and egalitarianism among sites became established by this period.

Thus, in the RBA and FBA, west-central Italy already exhibits the internal divisions that characterize its subsequent history. This is evident in the group

of sites already favouring each other in exchanges, forming a cohesive social network that was the prelude in each case to a common affiliation and eventually, an ethnic identity. It must be emphasized that with such a limited body of evidence we are at best catching glimpses of extant social groups. Nonetheless, these networks' location within the spatial limits of the heartlands of the later ethnic groups, the Etruscans and the Latins, is compelling evidence indeed. The early networks score high on measures of cohesion, as demonstrated, although given the small dataset the calculations are tentative, and best viewed with the hypothesized west-central Italy network serving as a control. The continuity does not extend to the scale of the individual sites, but at the regional scale, one may argue that the patterns of interaction did prevail over a long period. While the Proto-Latium subgroup is too small for its structure to be entirely convincing, the homogeneous and egalitarian structure of the Proto-Etruria subgroup, with no single site monopolizing centrality and influence, foreshadows the dynamics between the later Etruscan city-states, where some were more powerful and wealthy than others but none dominated. This tradition of egalitarianism is an instance of path dependence, and may be contrasted with southern Italy where a sharp bias towards coastal centres created a bipolarity in site roles that continued in the first millennium BCE (Blake, in preparation).

Interestingly Rome is the only site to be situated at the future border with Etruria: the other Proto-Latin sites and their Proto-Etruscan counterparts are clustered well away from the subsequent border zones. The manner in which both networks are concentrated in the heartland of the subsequent ethnic groups suggests that the ensuing ethnicization was an aggregative process. Here, ethnicity formation entailed building out from a core group to incorporate adjacent previously marginal people. This subsequent aggregation may have been tied to demographic growth as well: the bare patches between networks in the LBA may have been too thinly occupied to permit much more than a radical localism. This aggregative process may have resembled the model Jonathan Hall (1997) proposes for Greek ethnicization in the Archaic period, when, through myths of common descent, formerly separate groups come to emphasize affinities that allow them to share in a common Hellenic identity. Hall's main interest is in the elision of regionalism in favour of pan-Hellenism, but he notes that these regional identities could themselves be the products of similar processes (Hall 1997: 50). The aggregative process may be related to Nijboer's (2004) economic model of Archaic period urbanization in west-central Italy, in which the rise of extra-household craft industries compelled the forging of relationships with more distant sites, to ensure a large market. But given the linguistic divisions already in place between the Etruscan and Latin languages by the time they were written down in the Archaic period, it would seem more likely that the expansion of the networks and ethnic affiliations began earlier, in the Iron Age. This ethnic identity formation

would have both facilitated and constrained some of those new commercial relationships: facilitated in the sense that sites within each ethnic region were already tied, and constrained in that extra-regional ties would have been less easy to establish and maintain *ex nihilo*. This is not to say that these regions could function in total isolation. We can consider the extra-regional contacts examples of 'weak ties', in social network terms (see Chapter 10, this volume).

The social network analysis employed here broadens the range of approaches one may take towards group identity formation, moving beyond primordialist and instrumentalist bases to what may be termed an 'interactionist' model based on the notion of path dependence. This emphasis on recovering ancient groups from the bottom up rather than beginning with preconceived notions of them echoes Terrell's 'exploratory' approach to human history (Chapter 2, this volume), and is one of the strengths of social network analysis. This preliminary study will be expanded in a subsequent publication to include other regions of Italy. Comparisons with the early networks of regions that never achieved 'ethnic' status may help to establish a predictive model for ethnogenesis. In the meantime the case of west-central Italy demonstrates that the Etruscans and Latins may be able to trace their origins earlier than previously thought.

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# 10

## Re-thinking Jewish Ethnicity through Social Network Analysis

*Anna Collar*

### 10.1 INTRODUCTION

Between AD 66–135, the Roman province of Judaea was all but annihilated. As an iron-fisted response to various Jewish uprisings against Roman rule, both in Judaea and elsewhere, in AD 66 Vespasian ordered the siege of Jerusalem. By AD 70 the central and singular Temple of the Jews was in ruins. Jews were taken into slavery, and over the next half-century, Judaea was punished again and again, culminating in the uprising led by Simon Bar Kokhba in AD 132. By AD 135, this too was quashed: and Hadrian expelled Jews permanently from Jerusalem—a ban not lifted until the 4th century. Jerusalem was renamed Aelia Capitolina and the province Syria Palaestina. Judaism, its Temple and its self-assurance in tatters, underwent a series of fundamental reforms, dictated by the rabbis in Palestine and Babylon. These reforms were set out by highly educated religious leaders; but what of the Jewish lay-person, the farmers, the smiths, the ordinary men and women living their lives dispersed across the Roman world?

In this chapter, I use the epigraphic data for the Jewish Diaspora to argue that, if the rabbinic reforms of Judaism were necessitated by the destruction wrought in Judaea, then this cataclysm also 'activated' the ethnic network of the Diaspora Jews. Before the destruction of the Temple, Diaspora Jews did not define themselves (epigraphically) as such. I suggest that this was because there was an inherent centre to their religious life, manifest in the Temple. The destruction of the real and psychological centre of Judaism changed Jewish existence forever. I argue that the tenets of rabbinic *halakhah*—the laws and moral codes defined in the Mishnah—were swiftly transmitted across the newly activated ethnic network of the Diaspora, shown clearly in the epigraphic record as a renewed knowledge of the wider Jewish network.

## 10.2 SOCIAL NETWORKS, ETHNICITY, AND WEAK AND STRONG TIES

Ethnicity is a complex issue, as we shall see below, but it is a fundamental aspect of identity and one that defines individuals—both for themselves and for the people around them. One's ethnic heritage is essentially membership of a group, albeit sometimes dispersed, and there remains an element of common ground between separated individuals. In network terms, groups can often be identified as local clusters—comprising people who see each other regularly and who can be considered as connected by *strong ties*. This is the term used in sociology to describe people with whom an individual has close, repeated, and regular contact, with whom they share many aspects of their life, described by sociologist Mark Granovetter as 'a combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and reciprocal services' between the two nodes (Granovetter 1973: 1361). These are the people who have the most influence on an individual, because they are trusted and respected parts of a person's social network. However, most individuals' social networks are not entirely localized either—they are made 'global' by a few long-distance links, or *weak ties*; for example, our passing acquaintances. Because these weak-tie people are less likely to be involved with many aspects of our strong-tie local social network, long-distance weak ties make important connections between separate local clusters. This combination of local clustering and long-distance links is famously described as the 'small-world' network (Watts and Strogatz 1998). In a small-world network, because of the weak ties connecting the separate clusters, the distance between two nodes or people is never that great.

Long-distance weak ties between the clusters have the effect of joining up these local groups into one interconnected cluster, known by physicists as the *giant component*,[1] which brings all the nodes of the network into contact with each other. When a network is not connected by the giant component, events on the network are only felt locally. In social terms, long-distance links in a network were recognized as having real power in terms of the transmission of new information. Mark Granovetter's seminal 1973 paper, 'The Strength of Weak Ties', demonstrated the importance of these individuals that connect up different localized clusters—that 'span network distance'—to the spread of certain kinds of information. He looked at the way people received information about new jobs, and found that, because our acquaintances (the long-distance weak ties in our social network) have access to local clusters other than our own, they are highly effective at passing information about new jobs

[1] As opposed to the 'normal component', describing the set of nodes to which a node is linked, i.e. its 'cluster'. See Watts 2003: 45–6.

across the network. Our strong ties, our close friends and family, more usually form what is known in sociology as a 'closed triad'—the structural situation describing three individuals who are all likely to know each other, or else have other markers of strength, such as frequency or length of contact (Shi et al. 2006:1). This means they are less likely to come across information that we don't already know: our strong ties have a localized quality.

Granovetter develops this further: 'individuals with few weak ties will be deprived of information from distant parts of the social system and will be confined to the provincial news and views of their close friends. This deprivation will not only insulate them from the latest ideas and fashions but may put them in a disadvantaged position in the labor market, where advancement can depend [ . . . ] on knowing about appropriate job openings at just the right time' (Granovetter 1983). In our modern world of social networking sites, keeping abreast of events and opportunities outside our local cluster may be easier than before. It is also important to remember that *everybody* is both a weak and a strong tie, that identification as such depends on perspective, and that these classifications are flexible and subject to change.

Of course close-knit communities—the clustering of neighbouring nodes—occur more frequently than long-distance connections. The long-distance links transgress local cluster boundaries, forming shortcuts to other clusters: the 'small-world' is a global network phenomenon that arises from local network interactions. The weak ties that are the feature of small-world networks are especially good at 'simple' diffusion that does not require frequent contact or trust—like passing on information about new jobs, or infecting us with disease. However, these types of links do not generally exert great influence on people where fundamental issues of serious change or adoption of new ideas are concerned.[2] *Strong* ties do, because they are our closest family and most trusted friends. These people form the core of our social network, and so exert the most influence on our decisions when it comes to the 'complex' transmission of new ideas or information. These are the people and the networks we must focus on when thinking about the spread of new religious ideas.

However, the diffusion of information through strong ties is problematic, at least, mathematically. Theoretically, the path length of strong ties is classed as long; i.e. the information being transmitted must make lots of little hops through different clusters and so may take a long time to travel from one side of the network to the other. However, this is not the case in real life, and empirical social network data has shown that strong ties *can* still have a short

[2] Influencing people is more complex than presented here, as certain individuals, especially in the case of religious diffusion, missionaries, who may well come into a community as a 'weak' tie, can possess a characteristic such as great charisma, knowledge, status, technology, or wealth which will make them more likely to be influential.

path length; i.e. a network of strong ties still allows information to pass through it relatively quickly. Social physicists Shi, Adamic, and Strauss found that removing the weak ties in a test case did not disconnect the network; rather, 'the network sheds some nodes and shrinks modestly' (Shi et al. 2006). They concluded that a high-fidelity strong-tie social network, conceptualized as *overlapping clusters*, spreads information at almost the same efficiency as the small-world network linked together with long-distance weak ties. A combination of the two is the most accurate representation of the real world—where both overlapping clusters and weak ties connect the network.

## 10.3 THE JEWISH DIASPORA

The Jewish Diaspora in the Mediterranean offers a good set of data with which to explore these aspects of network theory: comprising, theoretically, a web of ethnically linked groups of people, with a universal notion of the distinctiveness of the Jewish people, faith, and laws. Since the concepts of the religion were transmitted in written form, increasing the potential for standardization, transportation, and access, there was an intrinsic unity to the dispersed Jewish community. Because shared Jewish identity involved most aspects of daily life, ethnic links can be understood in sociological terms as 'strong ties', the trusted bonds existing between friends and family, and therefore as extremely powerful for the transmission of social and cultural innovations.

Defining 'ethnicity' is a complex issue, as ethnicity itself is a fluid, socially constructed, and subjective aspect of identity, open to reconstruction, adoption, and redefinition by different people in different environments (see Orlin 2010). The epigraphic data mask subtleties of this kind, and must be taken at face value: those who chose to define themselves as Jewish are understood to be part of the Jewish *ethnos*. These defining markers are objective aspects of the record—but as Orlin says, 'subjectivity plays a large role here as well, for these attributes do not have independent significance; they become important for group membership only when the group invests them with the power to distinguish between in-group and out-group members' (2010: 15). Indicators of Jewishness in the epigraphic record are understood to have been used by the Jewish group for the purpose of self-definition: so my aim here is to test the communicative power that ought to be inherent in such an ethnic network. Assessing the network formed by the epigraphic material and how it changed over time draws a bottom-up picture of the developments in the Diaspora, and allows an understanding of how ordinary people marked their ethno-religious identity, and the reasons why the way they did this might have changed.

It is first necessary to briefly situate the Diaspora within an historical framework. At various points, the Jews were dispersed, whether by force or

voluntarily. The Achaemenids deported a large percentage of the population of Judaea to Persia, and the Hellenistic kings settled Jewish families in Asia Minor and Egypt. The Jewish historian Josephus claimed that there were Jewish communities in virtually every large city in the Roman world in the 1st century AD.[3] This means that, in different periods and places, and for different individuals, the integration or separation of Jews within the Graeco-Roman environment ranged from total assimilation to rigorous separatism, and Barclay points out that these levels would have differed between genders: 'the least assimilated Egyptian Jews were Jewish women who lived in wholly or largely Jewish districts' (1996: 118). There are many aspects of Jewish life and belief that were both highly regarded as well as vilified by their Greek and Roman neighbours—but constraints of space preclude their discussion here. Instead, I will simply examine the epigraphy for active display of Jewish identity.

Identifying features of Jewish inscriptions include reference to the synagogue, *proseuche*, 'prayer-house', or *gerousia*, although non-Jews also use all three. Likewise, offices within these domains—*archisynagogos*, *gerousiarch*, and *presbyter*—are all found in non-Jewish contexts, so texts that mention only one of these terms without further indicators are not included. Later examples use *rabbi*, but the term does not necessarily denote 'formal' priestly rank. Other clear indicators are Hebrew, Semitic personal names, and Jewish symbols (the *menorah*, *lulab*—palm branch, *etrog*—citron, and *shofar*—the trumpet, being the most common). We also sometimes encounter specific reference to the Laws or the Sabbath. A problem with the data is that, because they are often funerary, they are generally undated. As such, most are dated on palaeographic grounds, and so can cover large time ranges.

I will show that, beginning in the 2nd–3rd centuries AD, the epigraphic evidence, as the record of the lives of ordinary Jews, the largely static minority populations making up the Diaspora, underwent a stark change. In the early Hellenistic-Roman period, Jews integrated with Gentile communities, adopted Hellenized names and practices, and engaged with certain aspects of Graeco-Roman culture. Even though the Diaspora was considerable, there is very little evidence for Jewish self-identification, and where there is, it is limited to particular socio-political contexts: emancipation of slaves and the collective dedications of prayer-houses in Egypt.

The destruction of the Temple and the ensuing turmoil dramatically changed the lives of Diaspora Jews. The resulting tension with the Roman

[3] Josephus, *Ant.* 14. His quotation of a letter at 12.147–53 records the transportation of 2,000 Jewish families to fortresses and strategic places in Phrygia and Lydia, who were given land and permitted to live by their own laws. The authenticity of the documents Josephus uses has been questioned, and it may be that this letter was an apologetic document penned by Jews themselves (Barclay 1996: 260–2).

environment strengthened interpersonal bonds between Jewish communities, re-activating a dispersed 'strong-tie' network built on a new understanding of shared ethnicity. And we find also that the epigraphy shows the widespread dissemination and adoption of explicitly Jewish names, symbols, and language. By recognizing and interpreting this trend as the visible symbols of the new universalized *halakhah* of the rabbinic reforms, we may analyse these as a demonstration of how the community of the Jews created a dynamic network based on strong-tie 'familial' ethnic connections.

### 10.3.1 The Diaspora before AD 70

Although there is substantial literary evidence for the earlier Diaspora, a survey of the epigraphic material[4] from before the fall of the Temple shows that the occasions where Jews explicitly name themselves as such were very limited. Few individuals stated their Jewish heritage or ethnicity, and when they did, they did so for specific reasons. In Egypt, Jews had the distinct politico-legislative purpose of distinguishing themselves from Egyptians, to secure privileges from the Greek rulers. In the Black Sea, the Aegean, and the west, where we find singular rather than collective marking of Jewish identity, there is a clear connection with emancipation (*IJO* 1, BS9). Although the literature records Jews in Rome by the 2nd century BC, there is no material evidence for this. Likewise, Josephus records Jews settling in Asia Minor under the Seleukids; however, the only epigraphic evidence is a late Hellenistic inscription from Caunos in Caria that records a Samaritan family mostly with Greek names, including Dionysia and Cleopatra (*IJO* 2, 24). There were Jews in Cyrenaica and Cyprus during the Ptolemaic period according to Josephus, and the Cypriot Jews are known from three Phoenician inscriptions from the 4th century BC (*IJO* 3, Cyp 6; 7; 8).

However, the absence in most places of explicit statements of Jewish identity leads to the conclusion that Jews in the pre-AD 70 Mediterranean Diaspora responded to the Graeco-Roman world by assimilating to a degree that meant it was either unnecessary or even perhaps undesirable to identify oneself as Jewish, at least in inscriptions. Moreover, the occurrence on Jewish inscriptions of pagan theophoric names such as *Heraclea* at Delos (*CIJ* 1, 725), *Dionysia* at Caunos, and *Muttun-Astart*, 'gift of Astarte', on Cyprus, the evidence of a Jew who underwent incubation in a pagan temple in Boeotia (*IJO* 1, Ach 45), or the

[4] The analysis of the epigraphy relies on various corpora of Jewish inscriptions, Frey's *Corpus Inscriptionum Judaicum*, (*CIJ*), Ameling, Noy, and Bloedhorn's, and Noy, Panayotov, and Bloedhorn's *Inscriptiones Judaicae Orientis* vols. I–III (*IJO* 1–3), Horbury and Noy's *Jewish Inscriptions of Graeco-Roman Egypt* (*JIGRE*), and Noy's *Jewish Inscriptions of Western Europe* (*JIWE*), supplemented by the revised Schürer$^2$. Unless otherwise stated, inscriptions are in Greek, the *lingua franca* of the Diaspora even in Italy, making up more than two-thirds of the 900+ items.

fact that there are Jewish dedications in a temple of Pan in Egypt (*JIGRE*, 121–124) suggest that using pagan temples and names was not necessarily inappropriate or incompatible with Jewish ethnicity in the Hellenistic period.

This lack may be partly due to a strong centralized relationship with Jerusalem, implying an inherent Jewish identity that did not need external expression. A reference from Delos to Yom Kippur (*CIJ* 1, 725) shows knowledge of and participation in the Jewish festival year. These connections between Jerusalem and the Diaspora are also visible in the actions of Judaea's rulers. Inscriptions from Delos and Syros honouring Herod the Great show that the Diaspora was intimately connected to political events in Judaea; and an honorific inscription from the early 1st century AD from Delos, found in the propylon of the Temple of Apollo, was given by the Athenians for Herod Antipas, supporting the notion that the Delian community in particular was closely engaged with the political structures in both Athens and Judaea (*IJO* 1, Ach 38–39; 69; 74), and also that the leaders in Judaea were involved with the Diaspora even to the extent of donating to pagan buildings.

It seems clear from the lack of ordinary Jews in the Diaspora explicitly named as such, and the special situations of those who are, that before AD 70, Jewish culture and ethnicity in the Diaspora was somehow inherent and not prominently advertised. Jews were given pagan names, Jewish rulers donated to pagan buildings, and Gentiles were interested in Jewish cult. Because Jerusalem *was* the centre of Judaism in certain absolute and specific religious and fiscal terms, Judaism, with a book and the Temple at its heart, was understood by Jews to be fully formed. Jews engaged with and responded to the circumstances of their life in the Diaspora without losing this sense of attachment to the Jerusalem temple. However, when the emotional and religious heart of Judaism, enshrined in the Temple, was destroyed, how did the Diaspora react?

### 10.3.2 The Destruction of the Temple

The Jerusalem Temple in the Hellenistic-Roman period was a solid financial and religious focus for the Diaspora: both through the annual *didrachma* Temple tax levied on all men over twenty and the substantial numbers of pilgrims.[5] The generation of normative and accessible Jewish writings in Greek[6] aided this notion of centre. Goodman claims that for the Romans, the destruction of the Temple was an act of political machismo and posturing

[5] As recorded by Philo, *De Spec. Leg.* i 12 (69); and Josephus' reckoning of the numbers attending the festivals in Jerusalem at 2,700,000, *B. J.* vi 9, 3 (425). See Schürer[2] 1986 III.i: 148–9.

[6] Including the LXX, Sibylline Oracles, 2 Maccabees, and the letter of Aristeas, see Collins 1986: 61–86.

by Titus following the Jewish revolt, essentially an insignificant event in 'a comparatively minor provincial backwater' (1994: 43). For Jews, however, the destruction of the Temple marked a major change in the way Judaism was practised and conceived. The combination of the slaughter, subjugation, and impoverishment of the people of Judaea, the renaming of the province, and the destruction of the Temple itself had enormous psychological, spiritual, and financial consequences, kick-starting the period of the Bar Kokhba revolt and the rabbinic reforms, that led ultimately to the composition of the new book of laws, the Mishnah, *c.* AD 200. What about the situation in the Diaspora? The destruction is lamented in Diaspora works of literature, such as the Fourth and Fifth Sibylline Oracles (Collins 1986: 152). Josephus, writing *Contra Apionem* probably in the period following the assassination of Domitian, located the essence of Judaism in the rites of the Temple (Goodman 1994: 45). What then for Judaism when the rites of the Temple were no more? 'The only centre left to the people was the Torah' (Schürer$^2$ 1986: 513).

Aside from the psychological import, the most immediate changes for the majority of Diaspora Jews would have been the transformation of the Temple tax into the *fiscus Judaicus*, now payable to the Romans, and, in certain places, the influx of Judaean refugees or prisoners of war. The increased tension between Jewish communities and the Roman environment led to Jews turning inwards, increasing their reliance on an 'ethnic network' that had previously been less important. However, the longer-term effects of the destruction of the Temple on the Diaspora communities were cognitive, seen in the revolts that took place over the following fifty years. It has been argued that the Bar Kokhba revolt and the various violent revolts in the Diaspora in Cyrenaica, Cyprus, and Egypt, marked the 'powerful messianic expectations' (Hengel 1979: 655–86) of the dispersed Jewish nation. However, the revolts were all quashed, and instead, the most important reaction to the destruction of the centre is seen in the rise of rabbinic Judaism, which promoted a greater focus on the texts of the Torah and stricter adherence to the Laws governing norms of behavior—*halakhah*: it was 'precisely the annihilation of Israel's political existence which led to the triumph of rabbinic Judaism' (Schürer$^2$ 1986: 555).

### 10.3.3 The Transmission of Rabbinic Judaism in the Diaspora

The epigraphic evidence shows a massive increase in explicit statements of Jewish identity from the 2nd century onwards. I argue that this should be interpreted as evidence that the new religious authorities in Palestine used the highly influential strong-tie 'familial' connections of the ethnic network of the Diaspora to transmit the religious and social discipline of rabbinic Judaism. The reforms of rabbinic Judaism arose in Judaea and emphasized reading and

interpreting the Torah and standardizing norms of behaviour (Rajak 1992: 11–12). This reconstruction of Judaism and the new universalized *halakhah* are clearly manifest in the records of the ordinary people of the Diaspora. The indicators found on Jewish monuments that reflect an increased awareness of a common Jewish practice, history, and behaviour include specifically Jewish symbols as referents to a universalized ritual and the religious calendar, and the use of Hebrew as a marker of education and a revived knowledge of the sacred texts, Torah, Jewish Law, and Jewish history. In addition, the increasing use of specifically Jewish name forms provides a subtle indication of the universal engendering of a more strongly defined Jewish identity, matched by the trend during the 3rd–4th centuries AD for individuals to define themselves as 'Jews' or, more often, as 'Hebrews'.[7]

Williams has argued that the 4th–5th century Hebraization of names in the Diaspora was a reaction to Christianity's appropriation of Biblical names and the 'increasingly intolerant attitudes of the Christian emperors towards people of other religions' (Williams 2007: 192). However, because these changes begin to be enacted before Christianity was the state religion, I instead suggest that this represents the internal transformation of Judaism. To demonstrate this, I show Hebraization as a series of network maps, comprising the findspots of the pieces of evidence. The technique used is simple and well known: Proximal Point Analysis (PPA), where every known node is linked to its three closest neighbours. However, simple as it is, the technique allows some interesting observations to be made.

### 10.3.4 Proximal Point Analysis

The first PPA (Fig. 10.1) functions as a preliminary, static snapshot of the geographical pattern of data, showing nearest neighbours and hypothetical interactions and information flow between Diaspora communities. It highlights places of geographical isolation and connectivity, but does not reflect existing connections. It allows the initial observation of the geographically determined Diaspora network: the empty spaces, long-distance overland or maritime links, and some of the constraints that terrain imposed on communications.

Immediately clear are the long-distance links across the western and northern Diaspora, as opposed to the tightly integrated eastern networks of Asia

[7] This terminological change has been linked to the destruction of Judaea, but may be better explained by the renewed emphasis on Jewish history. However, it may simply be connected with how scholars have interpreted the term, i.e. dating inscriptions using 'Hebrews' later on the grounds of its use. See the recent discussion of a Latin inscription from Capri (Noy and Sorek 2007).

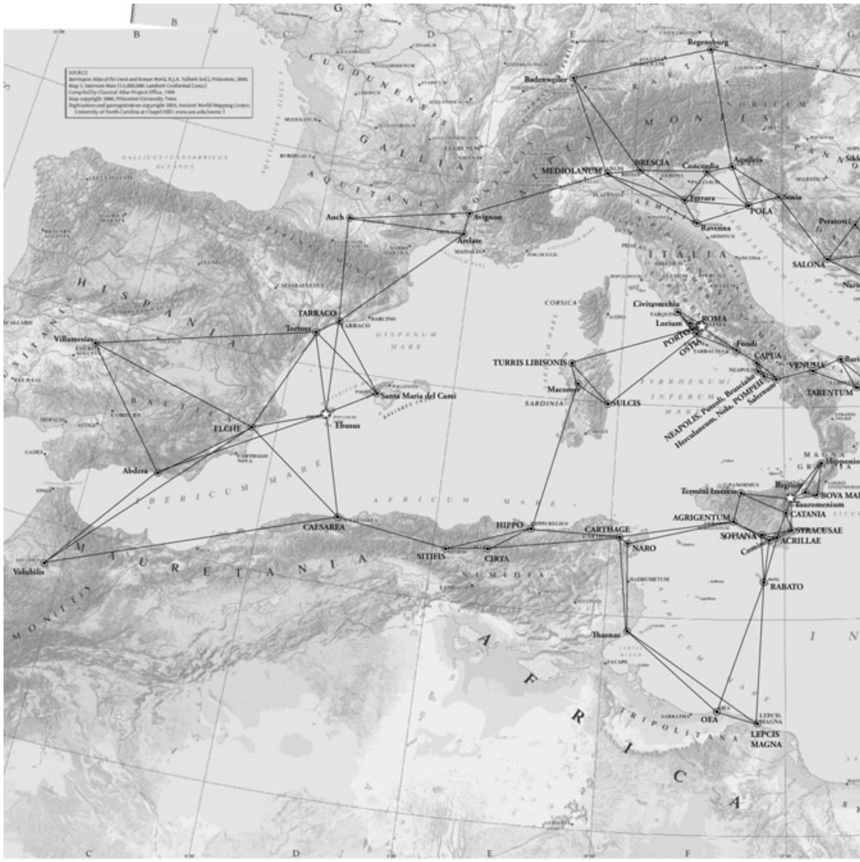



Fig. 10.1. Proximal Point Analysis of the Jewish Diaspora in the Mediterranean (star symbol denotes a place with six links).

Minor, Egypt, and Syria. In the west, Ibiza, Malta, and Sardinia provide links between Hispania, North Africa, and Rome, with Ibiza and Rome emerging as centres. There is a clear disconnect between southern Italy, linked via the major immigration port of Hydrantum to Greece, and the northern Italian sites around the Po valley. This reflects a divide between the two areas, highlighting patterns of local interaction and the different origins of their Jewish communities. The sparser network in the northern Adriatic is composed mainly of single finds, suggesting that the Jewish presence here was superficial. The epigraphy supports this: the only evidence from Ravenna is an amphora fragment inscribed in Hebrew (*JIWE*, 10), and the find from Concordia is an epitaph for the wife of a soldier from Emesa in Syria (*CIJ* I, 640). The larger, more established communities are later: the inscriptions from Brescia and Mediolanum date from the 4th–5th centuries.


The most striking thing about the western Diaspora is the separation of Magna Graecia from the rest of Italy, and the clear importance of Sicily as a local network, connecting with Malta, Carthage, and Calabria. Malta seems to serve as a communications hub between Sicily and Africa. Another interesting area is the pocket of introspection along the Danube *limes*, which must be connected with the military camps—indeed, a *praepositus stationis* made a dedication in the synagogue at Intercisa (*CIJ* I, 677). The long-distance links into Raetia and Germania Superior are misleading, as both of the finds (*CIJ* I, 673; 674) are portable amuletic texts that may not actually have been used by Jews per se, although they do show that Jewish *religious ideas* were attractive and taken far beyond places where there were established communities.

Moving east, although northern Greece, Moesia Inferior, and Thrace also have long-distance links west into Dalmatia via Stobi and Doclea, and east into

Bithynia through Chalcedon, their communities were bigger, with attested synagogues. The missionary journeys of Paul into northern Greece also testify to the importance of these places in the Diaspora, and also to the intercommunications between them, regardless of their geographical distribution. By contrast, the network in Asia Minor is tightly integrated and even, presenting a picture of regular low-level interactions.

Although the analysis takes no account of geographical costs or directionality, the network reflects the geographical features of the landscape. The sites in Lycia, Pisidia, and Pamphylia mainly connect amongst themselves and along the coast of Cilicia, rather than across the high mountains of internal Lycia. This creates a pocket of introspection, supported by the fact that most of these are single inscription findspots. However, this area links to Apollonia in Phrygia, noteworthy because the inscription makes explicit the connection: the epitaph of Debbora, of Pisidian Antioch, who married Eumelos from Sillyon in Pamphylia (*IJO* 2, 180). Amastris provides the only link to the communities of the north shore of the Black Sea, which are otherwise completely isolated. The centrality of Panticipaeum, and the remoteness of the Black Sea sites probably reflects reality. Although the Diaspora was well established beyond the Roman Empire, the Roman-Parthian/Persian frontier will have restricted communications in this direction.

On first impressions, the Cypriot network appears introspective, with only a couple of links from the north to the Cilician coast. The high mountain ridge between north and south does not divide the network, until we recall that in the early period, Jews are epigraphically attested only on the eastern side of the island, at Kition in the 4th century BC (*IJO* 3, Cyp7–9), and in the 1st century BC at Kourion (*IJO* 3, Cyp5). The link to the Near East at that time is explicit—the inscriptions at Kition are in Phoenician. There were many Jews in Salamis, as attested at Acts 13:4. The strong communications between Cyprus and Judaea continued, as the Jews revolted under Trajan, demonstrating interaction with Palestine and the rest of the Diaspora. However, the network connectivity has been skewed by the post-banishment (Schürer[2] 1986: 68) return of Jews in the 3rd–4th centuries. This has reconfigured the network on the island: masking the links with Phoenicia, creating a stronger internal network, and highlighting instead new links to Cilicia.

Egypt and Cyrenaica are the only parts of the network that are entirely isolated. This is quite accurate, as the Egyptian Diaspora was well established and, as a consequence, fairly introspective. The PPA misses Alexandria as a major Mediterranean hub, but the lack of an emergent centre in Egypt suggests that the population was evenly diffused. Cyrenaica is also entirely introspective.

This initial analysis captures pockets of isolation, and this reflects the real situation that may have existed in the agricultural hinterlands of Asia Minor, Egypt, Cyrenaica, and the Black Sea. It is notable that two of these more

introspective areas, Egypt and Cyrenaica, were regions where Jewish rebellions occurred. The divide between north and south Italy is probably reflective of reality, although the gravitational pull of major cities is absent, and as a result the Jewish communities in Rome, as well as Alexandria and Jerusalem, do not look very important. This is partly to do with the fact that this model does not have different costs built in for land and sea connections—a more complex version of this analysis could factor these in. This analysis is also only built on epigraphic data, and a more developed version could include literary evidence, which would add a more realistic gravity to these three major cities.

### 10.3.5 Networks Over Time: Hebraization

Following from these initial observations of clustering and isolation, we now build in the date range of the evidence for Hebraization, mapping *only* those finds that use Hebrew, Jewish symbols, or make explicit reference to Israel. New nodes this time connect not to their three closest neighbours, but to Judaea and to one established connection. This series responds to what is known of the date range of the evidence, by mapping findspots in hundred-year blocks, and builds into the network the role of Judaea as the place from which the reforms were disseminated as well as attempting to simulate more localized contact and exposure to Hebraization. Rome is also treated as a centre of gravity.

Although this skews the maps towards having very long-distance links and makes Judaea a heavy centre, it acts as a counterpoint to the initial, unweighted PPA and creates a picture of more 'realistic' interaction patterns, the idea of rabbinic 'mission' to the Diaspora, in which places were first exposed to the reforms, and subsequent localized spread of information. It simulates potential routes of information transmission from community to community, and also from a central authority, highlighting the growth of localized centres and clusters. The spread of *halakhah* was driven by the rabbinical centres of Palestine and Babylon, but the models also suggest potential routes of a more organic process of contact and adoption.

### 10.3.6 First and Second Centuries AD

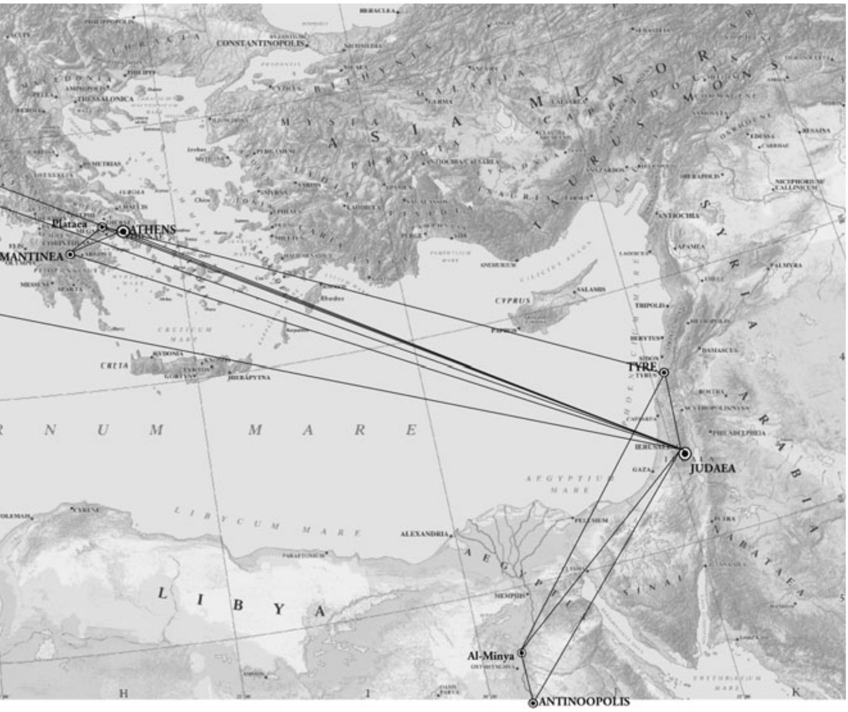
Fig. 10.2 comprises the sparse evidence for the early stages of Hebraization after the destruction of the Temple and the Bar Kokhba revolt. The links are naturally very long. Some are not connected with the rabbinic reforms; for example, the amphora fragment inscribed with Hebrew from Ibiza simply implies long-distance trade with Judaea (*JIWE* 178), and the evidence from Pompeii is connected with slaves taken to Italy after the Jewish Wars (*CIJ* 1, 562). However,


**Fig. 10.2.** Hebraization in the Jewish Diaspora: 1st–2nd Century AD.

the targeting of the established communities in Rome and Athens, and to a lesser extent Egypt, is fairly clear. It is more interesting however to look at the *gaps* in the network, which for Cyrenaica and Egypt can be plausibly connected with the heavy-handed quashing of revolts there, but in Asia Minor are quite striking. Presumably, attempts to bring the reforms into these well-established communities (as highlighted by the missionary journeys of the Christian apostle Paul through the synagogues of Asia Minor) were less successful.

### 10.3.7 Third Century AD

The jump in the network connectivity in the 3rd century is impressive. What is immediately clear in Fig. 10.3 is that Hebraization was not an organic process, spread through geographically proximate places, but rather a pan-Empire phenomenon: from Caesarea in Mauretania to Pannonia, from Sicily to the Black Sea. Many of the places where Hebraization can be identified at this stage are coastal—Carthage, Catania, Hydrantum, Kos, and Corycus, highlighting the importance of geographical position within the network for exposure to and acceptance of new religious ideas. However, the sites in the hinterland of Asia Minor also begin to open up at this stage, notably in Phrygia and Bithynia. A reason for this might be




found in the contemporaneous flourishing of Christianity in internal Asia Minor, which although it did not drive the process of Hebraization, was a localized change in the dynamics of the Jewish communities. Hebraization also spreads into Syria, although only to a superficial degree at this stage.

### 10.3.8 Fourth Century AD

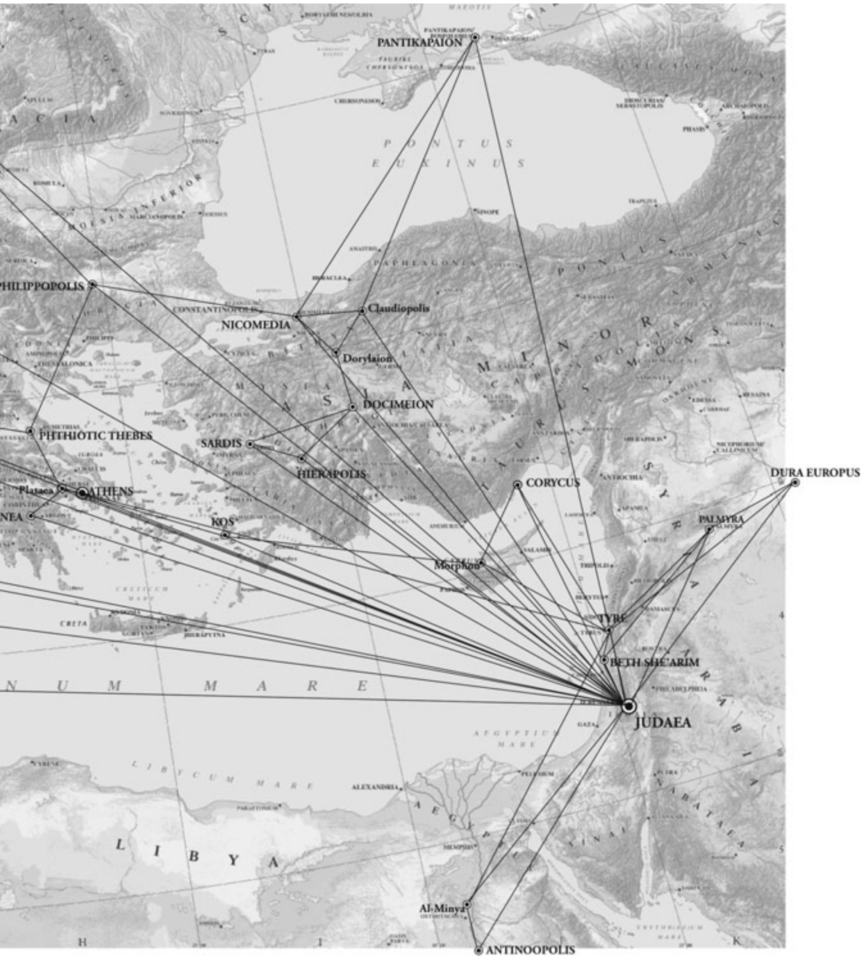
The process in this period (see Fig. 10.4) becomes more organic in Asia Minor, Syria, and Sicily. The communities on the coast of Ionia are drawn inland towards the tightly interconnected sites in Phrygia. Phrygia becomes the connective corridor to the sites in Bithynia, with Nicomedia emerging as a centre between the Black Sea sites and the rest of Asia Minor. This highlights an increase in cross-Euxine connectivity centred near the Bosphorus that may reflect that Nicomedia was Diocletian's capital from the late 3rd century until the final transferral of Rome to Constantinople in AD 330. A similarly tight network emerges in the sites round the southeast corner of Sicily, including Malta, and likewise in Syria. The network between the communities on the heel of Italy probably represents a similarly introspective process. The evenly distributed pattern in the well-established communities of Thessaly and Macedonia may result from prior exposure to the phenomenon. The network in


**Fig. 10.3.** Hebraization in the Jewish Diaspora: 3rd Century AD.

the west appears more centralized than in the east, reflecting the continuing importance of Rome. The lack of an eastern centre outside of Judaea is therefore particularly noteworthy.

### 10.3.9 Fifth–Sixth Centuries AD

Fig. 10.5 shows a deepening of the process, especially at a localized level. The notable growth in the east is in the region of Constantinople, creating an area of introspection, reflecting the new capital's gravitational pull. In the west, Hebraization spread through the locally integrated networks of communities in Sicily and Calabria. The geographical distances in the western network are




longer than in the east, suggesting that the network was of a different quality. It may indicate that either the west was more centralized around the Roman hub, or alternatively that the places on the coast of Spain were more cosmopolitan and had long-distance links elsewhere. This may find support in an inscription mentioning Cyzicus in Asia Minor, which was found in Tarragona (*JIWE*, 186). The sites along the coast of Spain and southern France make up an almost separate network, which may reflect the disintegration of the centralizing Roman force: it was during this period that the western provinces came under Barbarian control and the Empire split.

What the use of networks helps to show is how Hebraization as the visible remains of the pan-Judaic universalizing reforms might have moved across the Diaspora. The analyses suggest that it was a centralized process, occurring throughout the Roman Empire during and after the 3rd century. It may be that certain large Jewish communities were 'targeted' for reform, for example, Sardis,

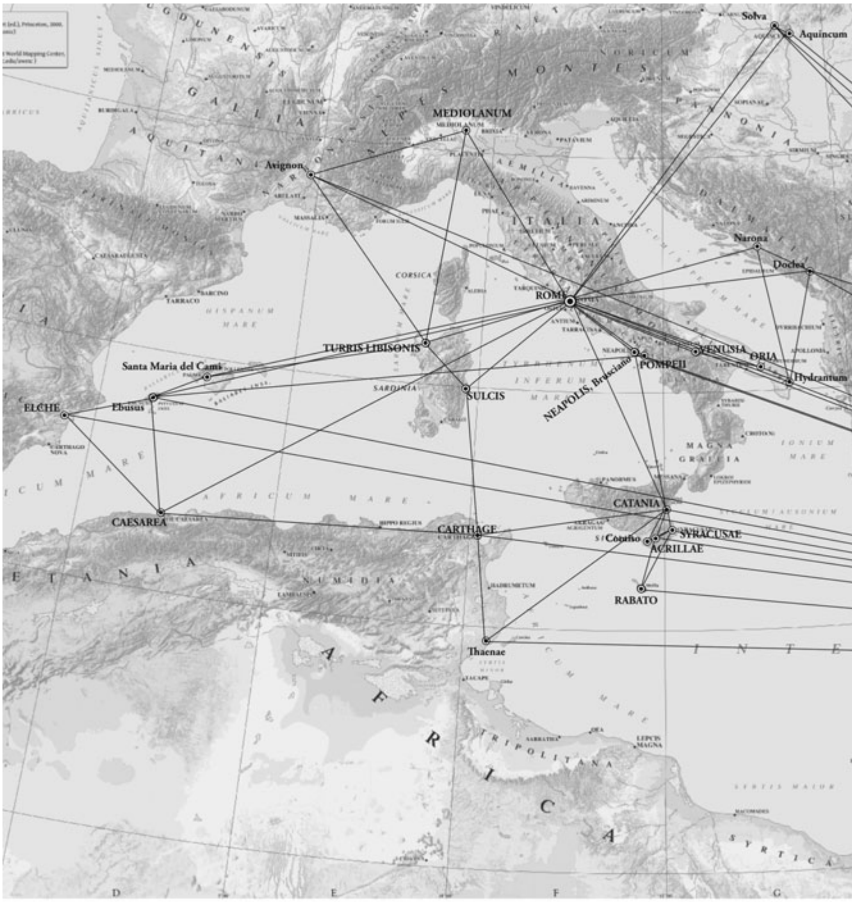
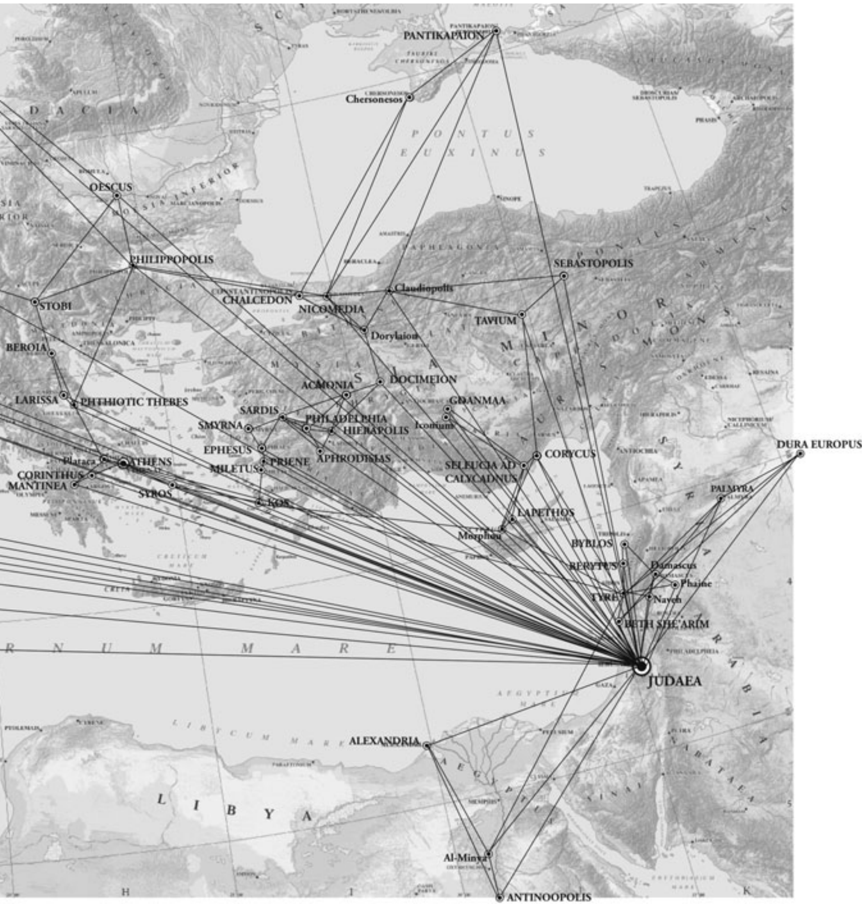



**Fig. 10.4.** Hebraization in the Jewish Diaspora: 4th Century AD.

Athens, and Rome. It has shown the difference in the network structure in east and west, in particular the more regular eastern network, especially in Asia Minor, implying a more organic adoption based on localized interactions. Further, the models have highlighted areas of introspection and more gradual diffusion (Sicily and Syria) and shown that some places were more receptive to new information. It has also illuminated some interesting lacunae—namely, Egypt, explained by the Egyptian Jewish revolt that destroyed a large part of the Jewish population.

### 10.3.10 Conclusion: Activating 'Familial' Networks of Ethnicity

Contrary to recent claims that the rabbis in Persia 'abandoned' the western Diaspora (Edrei and Mendels 2007), this analysis has shown the on-the-




ground adoption of the rabbinic reforms, and that the Jewish communities in the Roman Empire underwent a Diaspora-wide process of Hebraization, starting in the 2nd century AD. The destruction of the Temple in Jerusalem and the subsequent quashing of the Bar Kokhba and other Diasporan revolts changed the situation of Jewish communities both in Judaea and in the Diaspora: Judaism ultimately turned inwards. A newly heightened sense of persecution ‘re-activated’ the familial ethnic bonds already in existence, encouraging the susceptibility of the strong-tie network to religious innovation. The rabbinic reforms were spread in this way.

The rapid and universal process of Hebraization, manifest epigraphically in the use of Hebrew, Jewish symbols, and the rise in popularity of explicitly Jewish names, could be understood in network terms as the result of an ‘information cascade’ (see Watts 2003). The strong-tie ethnic connectivity of the Jewish Diaspora that was activated in the years following the destruction of the Temple and the Bar Kokhba revolt made the network increasingly

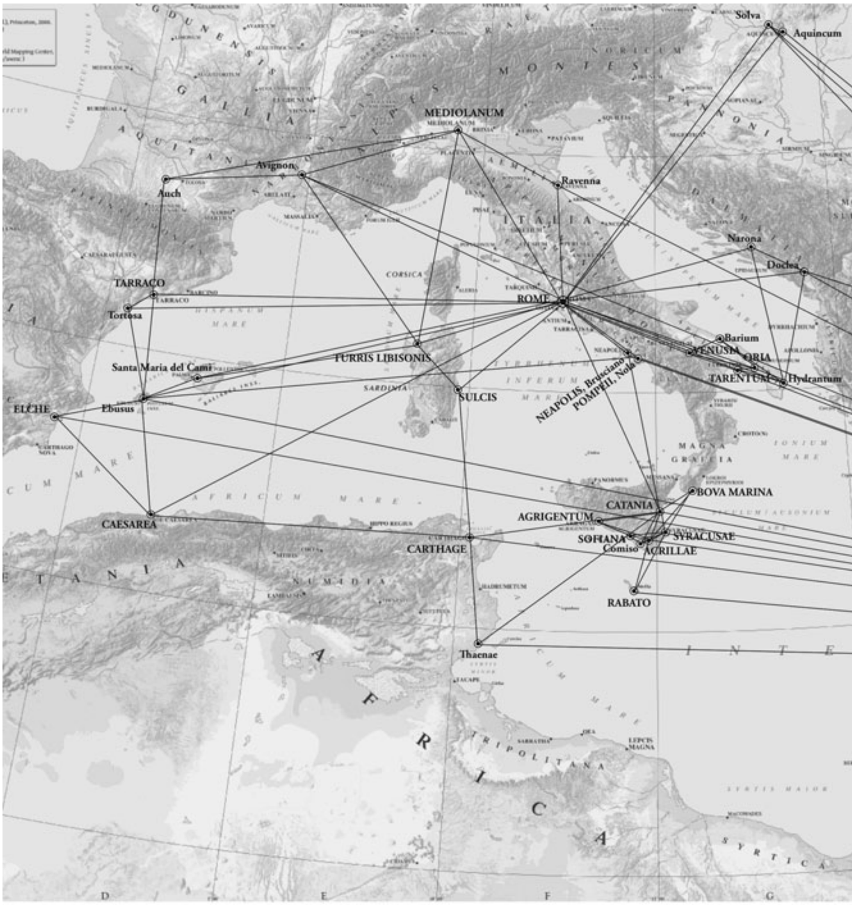
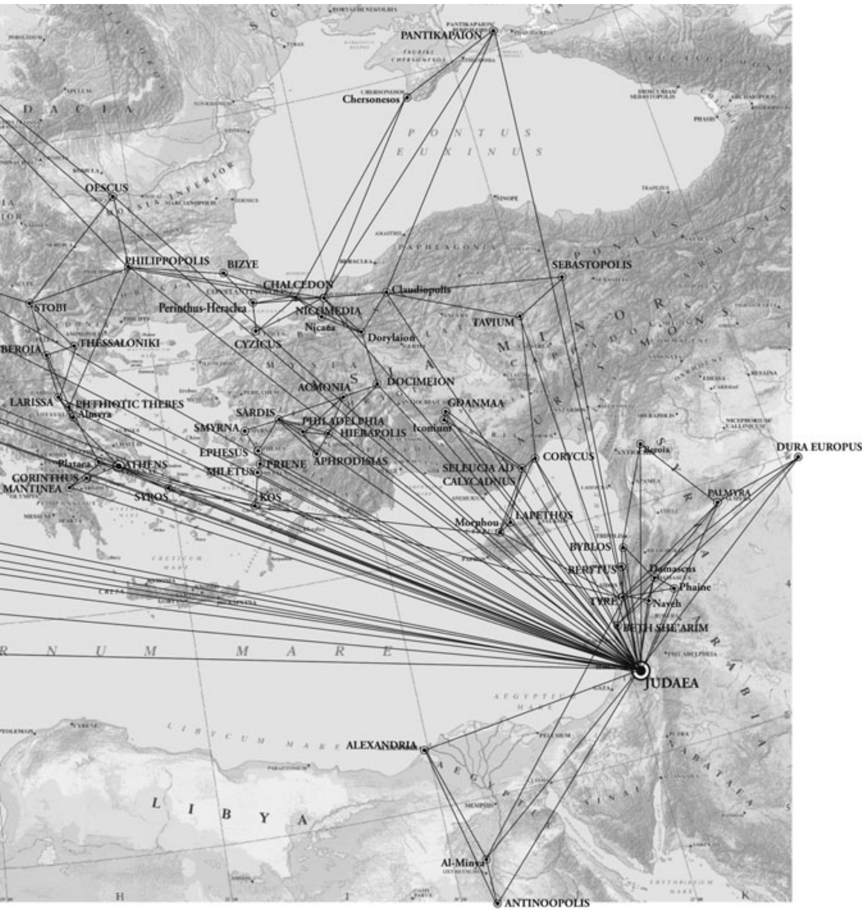



**Fig. 10.5.** Hebraization in the Jewish Diaspora: 5th–6th Century AD.

susceptible to religious innovation. The 'real-world' network, consisting of the strong ties of ethnic bonds in combination with the influences of weak-tie (but also ethnically strong) missionaries or carriers of the new information, means it could be argued that the Jewish Diaspora became what is known as a 'percolating vulnerable cluster' (see Watts 2003), in other words, it was absolutely ready for change: and the religious authorities in Palestine used it to transmit the rabbinic reforms.

But it was not just the rabbis: Christianity made a similar use of the same strong-tie ethnic network and the sense of anxiety and persecution that was latent in the Jewish communities at the end of the 1st century. Pauline Christianity was marked by the application of linguistic terms for close family to all those who lived in the community of Christ. The creation of an ethnic




'pseudo-family' is a commonly used persuasive rhetorical device to highlight the ethnic bond between Paul and his audiences—he addresses the mob in Jerusalem at Acts 22, calling them 'brothers and fathers', and again when he addresses the council of chief priests—and it has the effect of creating a cognitive strong-tie network bond between them. The Acts of the Apostles always refers to the Christian 'believers' as 'brothers' (for example, Acts 1:15; 3:17) and as such, reinforced the social ties that bound them. Christianity was able to persuade and convert effectively both by utilizing the *actual* strong-tie familial network of the Jewish Diaspora, and by simultaneously *manufacturing* a new one for believers in Christ.

Because the Jews were ready for change, the network they formed was highly susceptible to the religious innovations brought by people who preached change. Martin Hengel has argued (see above) that Diaspora Jews had strong messianic hopes in the decades following the destruction of the Temple, manifest in various revolts and also in the person of Simon Bar Kokhba. At the same time, the sect of Christianity believed that it *already* offered a messiah, and also an explanation for the cataclysm—punishment of the Jewish people by God for failing to recognize the divinity of his Son. Rabbinic *halakhah* and Christianity are different manifestations of the same cognitive response to the disasters that befell the Jewish people, and both required an internal change in the religion: promoting better adherence to Laws and moral codes. Both used the same type of strong-tie social network to transmit their message, and both swept across the Roman Empire.

This analysis shows that, when thinking about the application of networks to examine or explain archaeological or historical datasets, we must be prepared to reassess the theories we use. The 'small-world' network phenomenon is a fantastically useful heuristic device for approaching ancient data—but we must not lose sight of the human and social aspects of the worlds we study. Weak ties are powerful, it is true: but strong ties have the power to change the way people think and believe. Network studies will benefit from paying further attention to the potentially long-range effects of strong ties, which are often assumed to operate only at a local cluster level.

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# 11

# Grounding the Net: Social Networks, Material Culture and Geography in the Epipalaeolithic and Early Neolithic of the Near East (~21,000–6,000 cal BCE)

*Fiona Coward*

## 11.1 INTRODUCTION

The Epipalaeolithic and early Neolithic are often considered highly significant periods in the development of human culture. Traditionally, research into the period has focused on changing subsistence and economic strategies, including increasingly sedentary lifestyles and the adoption of new subsistence practices involving closer control of plant and animal species that ultimately resulted in the genetic changes now described as 'domestication'. However, more recently attention has shifted to the *social* implications of these developments (e.g. Kuijt 2000a). Changes in architecture and the use of space (Banning and Byrd 1989; Byrd 1994; Kuijt 2000b; Goring-Morris and Belfer-Cohen 2003, 2008), burial practices (Byrd and Monahan 1995; Goring-Morris 2000; Kuijt 2000c; Hayden 2004; although see also Belfer-Cohen 1995), art and symbolism (Bar-Yosef and Belfer-Cohen 1999; Cauvin 2000; Watkins 2004a), and material culture in general have all been hypothesized to indicate, and indeed to constitute, significant changes in social life (see e.g. Kuijt and Goring-Morris 2002 and chapters in Kuijt 2000a for discussion) at this time. Indeed, the shift to settled, agricultural village life is often held to represent the foundations of a way of life that still characterizes modern *Homo urbanus* (Runciman 2005: 29, 130–1; Watkins 2004a: 16; Cauvin 2000: 72), a majority urban-dwelling species (UNFPA 2007) living at extremely high densities in agglomerations frequently numbering millions of individuals.

However, criticisms of this neat origins myth of modern city life (e.g. Gamble 2007; Coward and Gamble 2008; Coward 2010a) have emphasized

the need for these hypothesized changes in social structure over the course of the Epipalaeolithic and Early Neolithic to be demonstrated more robustly using large, empirical datasets. Research exploiting the potential of social network analysis to address these issues has indeed generally supported a model of social change at this time (Coward 2010a, b, in press), but has also identified the process as a much longer-term one than previously thought (e.g. Coward and Gamble 2008; Coward in preparation). In addition, it has highlighted some specific aspects of the process which require closer attention—in particular the role that material culture plays in the geographical scaling-up of social relations, and the significance of geography for the structure of social networks.

This chapter will focus on the latter of these issues. It will first briefly discuss the basis for empirically studying social change using SNA to analyse patterns of material culture distribution in order to infer social relations between and within groups in prehistory, then review previous work in this area before focusing on the significance of geography for the structure of social networks by examining the interaction between material and social networks over the course of the Epipalaeolithic and early Neolithic. In particular, I will focus on one significant aspect of the scaling-up of social systems that may have occurred over this period—that of the increasing supplementing of relationships based largely on geographical proximity with 'weak ties' that are largely, if not completely, a-spatial.

## 11.2 SOCIAL NETWORK ANALYSIS TECHNIQUES AND CHANGING SOCIAL NETWORKS OF THE EPIPALAEOLITHIC AND EARLY NEOLITHIC

### 11.2.1 Social Network Analysis

Sociological research among contemporary individuals and groups frequently uses social network analysis methodologies to investigate individual interactions and the ways in which these are embedded in, structured by, and indeed constitute, broader social structure.

At its heart, SNA relies on the insight that social entities (individuals, groups etc.) can be considered nodes in a wider network, each connected by potentially multiple relationships to other such entities/nodes. In more complex formulations such relationships can be directed if ties are not necessarily reciprocated, and relationships also can be valued according to self-report or by objective assessment of various criteria (number of interactions per unit time; time spent interacting etc.). In addition, multiple different types and/or

contexts of interaction can be considered using multiple, 'layered' (known as *multi-modal* or *multiplex*) networks in which different types of relationship (family, friendships, work colleagues, etc.) between individuals, their context or mode of interaction (e.g. face-to-face, telephone, email), and intensity and/or duration of those interactions may be distinguished from one another. The ability of SNA techniques to handle the combinations of value and significance ascribed to individual relationships and the modes and contexts of the constituent interactions thus allows us to tease out the many different facets of our social lives (see e.g. Wasserman and Faust 1994; Hanneman and Riddle 2005 for further discussion).

Another significant property of SNA is that this very simple and intuitive way of thinking about relationships also allows us to access broader social structures. Social network structure is historical, in that the interactions any individual engages in today, or indeed tomorrow, are strongly influenced by past practice and pre-existing ties forged in earlier interactions. We do not have a completely free hand in our interactions, but the social structure that constrains us is also produced, reproduced, and altered by our own actions over greater timescales than those of discrete interactions. Furthermore, the networks described by these interactions and structure are multi-scalar. Nodes can represent individuals—however, they can also represent aggregate entities in broader systems, right up to the level of the corporate, national, and multinational conglomerate.

### 11.2.2 SNA in Prehistoric Contexts?

SNA methodologies are thus extremely useful for investigating social relations and broader structure and the interplay between these scales of analysis among contemporary group. However, in contemporary settings social relations can be observed or obtained from the participants themselves. In archaeological and especially prehistoric contexts, all interpretation, including that of the social interactions and structure of past societies, must be reconstructed via the material traces that such interactions may (but do not always) leave. Nevertheless, there are compelling reasons to suggest that SNA may also be applied to archaeological contexts. In SNA such techniques are routinely applied to a variety of different kinds of social entities, particularly at larger scales of analysis, where the relationships linking nodes together are often extrapolated from a variety of resources, frequently including the transfer and distribution of material resources such as money or trade volumes (Sangmoon and Hang 2002; Bhattacharya et al. 2008; Wang 2009; see also Wasserman and Faust 1994, chapter 2 for further discussion).

The reconstruction of material distribution patterns is of course something that archaeologists are already extremely familiar with; the study of trade and

the dissemination and distribution of material culture in the archaeological record has long been a topic of considerable interest to archaeology in a wide variety of temporal and geographical contexts (Renfrew et al. 1968; Hodder 1974; Renfrew 1975; Plog 1976; Renfrew and Dixon 1976; Earle and Ericson 1977; Ericson and Earle 1982; Renfrew and Cherry 1986), and is routinely interpreted in terms of what it can tell us about wider social networks and relationships between social entities. Such interpretations hinge on the fact that material transmission and dissemination occur as part of a wider system of social relations. Diffusion of innovations and traits and the social practices involved in trade, exchange, and gifting is dependent on the intensity and duration of communication and interpersonal contact between individuals and groups (Hägerstrand 1952, cited McGlade and McGlade 1989; Collar 2007; Lu et al. 2009; Coward 2010a), to the extent that the spread of ideas and objects is often modelled in a similar way to epidemiological models of the spread of disease (see e.g. Granovetter 1973; Steele 1994; Barrat et al. 2004; Dodds and Watts 2005; see also Coward and Grove 2011: 117–18 for discussion).

Furthermore, there is a strong basis for believing that material culture is more than simply a passive reflection of, or archaeological proxy for, wider social relations, but that material objects instead constitute *part of* the process of negotiating and maintaining those relations (e.g. Appadurai 1986; Miller 2005; see also Buchli 2004 for review). New approaches in archaeology and beyond are increasingly emphasizing the significant role played by material culture in social interaction and even in memory (e.g. Connerton 1989; Watkins 2004b) and cognition (Hutchins 1995; Clark and Chalmers 1998; chapters in Malafouris and Renfrew 2010). For example, in theories of material engagement (e.g. chapters in DeMarrais et al. 2004), mutuality (Gosden 1994), and Actor-Network Theory (Latour 1996; Law 1999; Whatmore 2002, 2006), material culture (along with animals, plants, and all kinds of other entities) is often considered a fundamental part of the same social network as individual human persons and objects, which may acquire biographies and identities and in some circumstances be considered agents and persons in their own right (Strathern 1988; Hoskins 1998; Gosden and Marshall 1999).

Increasingly, such 'network' ways of thinking about the diffusion of innovations and/or material culture are challenging monolithic 'culture-history' approaches to the past, and traditional archaeological 'cultures' defined by material culture distributions are increasingly being viewed as the result of social interactions between individuals and groups selecting from broader oeuvres of material practice available to them according to local conditions, histories, traditions, and contexts of interaction (see e.g. Asouti 2006 for further discussion) as well as the properties and qualities of the material culture itself.

As a result of these theoretical developments, archaeology is increasingly embracing SNA methodologies, as the chapters in this volume attest. However,

thus far many of the applications of SNA to archaeological datasets have been in historic contexts, drawing from textual records documenting trade or itineraries of travel (Graham 2006; Isaksen 2008), and, further, have mainly been applied to island or circum-marine groups of sites, particularly the Pacific Islands (Irwin 1983; Hage and Harary 1996), and the Mediterranean and Aegean archipelago (Broodbank 2000; Evans et al. 2008; Brughmans 2010), as well as in the Baltic (Sindbæk 2007). Furthermore, many of these applications of SNA in archaeology have focused on individual 'snapshot' pictures of social networks at a particular point in time. While these studies are certainly informative and interesting pieces of work, they rarely set out to investigate how these networks *change* over time—and those that do tend to model change using mathematical approaches rather than directly from the archaeological data (Broodbank 2000; Evans et al. 2009; although see e.g. chapters in Flannery 2009 [1976]). Such studies of course provide valuable models to which the archaeological record can be compared, and certainly avoid the perennial problem of the incomplete archaeological knowledge of regional settlement systems. However, such models also inevitably build in a number of assumptions regarding the likely trajectories of network change over time, rather than examining the changes reflected in the archaeological record itself.

### 11.2.3 Investigating Social Change in the Epipalaeolithic and Early Neolithic

Previous research has applied SNA techniques to the study of the ways in which the social and material networks reconstructed from the archaeological record changed over the course of the Epipalaeolithic and early Neolithic of the Near East (Coward 2010a, b; Coward in press). This research used a database of material culture from well-dated sites of these periods to establish indices of material culture similarity or closeness for each pair of sites (the nodes) dated to within the same 1,000-year 'timeslice'. This measure of similarity was interpreted as reflecting the strength of the social relationship between the sites, which is seen both as structured by and structuring the gifting, trade, and exchange of individual items and/or the dissemination of the skills of manufacture and the practices and contexts in which items were used. These pair-wise measures of material culture similarity were used as the basis for adjacency matrices from which a number of network properties could be calculated for each 1,000-year network, and the temporal trends in these measures ascertained (see Coward 2010a, b for more detailed discussion of how the analyses were conducted). Subsequent work exploited the multi-scalar capabilities of SNA in conducting complementary analyses at the intra-site level, using individual burial contexts as nodes, connected by shared material culture elements of mortuary practice and performance (details in Coward in press).

Results (Coward 2010a, Figs. 21.3, 21.4) suggested that, at the inter-site level, social networks became larger and more fragmented over the course of the Epipalaeolithic and early Neolithic. However, the average strength of relationships between sites ('degree'), and the overall density of the networks (the proportion of the maximum possible strength of ties that is actually realized) both increased. This was a surprising finding given that the time and energy costs of maintaining large numbers of relationships (Dunbar 2008; see also Roberts 2010 for further discussion and references) mean that there is usually an inverse relationship between network size and intensity or density of ties (see references and discussion in Wasserman and Faust 1994; Hanneman and Riddle 2005; Lehmann et al. 2010). However, it was clear that later networks sampled an increasing diversity of material culture, with many more different types of material culture contributing to adjacency matrices. For example, the thirteen sites dated to between 18 and 17kyrs BC shared a total of only seven different kinds of ground stone artefact, while the forty-one sites dated to 7–6kyrs BC yielded twenty-four. To correct for this, every cell of each matrix was divided by the total number of different kinds of material culture sampled in that timeslice to give a measure of the strength of relationship between each pair of sites relative to the maximum possible strength for that network. Thus normalized, average degree, density, and average network distance between pairs of sites in each network were shown to decline over the period, as might have been expected given the increasing numbers of sites making up the later networks (see Coward 2010a for a more detailed discussion of these results).

A slightly different pattern was seen at the intra-site level. As was the case in the inter-site analyses, average measures of material culture similarity (degree) between burial contexts increased over time—a pattern again related to the much larger oeuvres of material culture employed in later sites, as normalizing for this (as described above) removed this trend. However, measures of fragmentation did not change significantly over the period, and overall density in fact declines over time; early burial contexts are very similar in terms of the kinds of material culture and practice involved, but later burial contexts draw differently from a greater range of possible options, resulting in greater individualization of burial performances.

Coward argued that these patterns suggest a process in which the trade, exchange, and referencing of material culture within and between sites may have helped offset the increasing costs of larger social networks by allowing individuals and groups to maintain more links with others despite the increasing scale of the system (Coward 2010a; see also Coward and Gamble 2008). Nevertheless, the decline in density of intra-site social networks over time suggests that individuals' relationships with others in their increasingly large and permanently co-resident groups were coming under pressure, despite the increasing elaboration of material culture.

Such a picture accords well with ethnographic and sociological observations of social structure at different scales. Traditional hunter-gatherer societies are very open and ephemeral (humans are a classic 'fission-fusion'-organized social species; Aureli et al. 2008), and the major and perhaps only stable social 'units' are the lowest, 'intimate' level of the hierarchy of social groups, typically kin and close friends (see e.g. Gamble 1999: 58–62 for discussion and references), as is the case in the relatively low-degree but dense and tightly clustered early social networks documented here.

Increasing group size, documented by the many larger sites known from later periods of the Epipalaeolithic and early Neolithic in the Near East (e.g. Kuijt 2000b) is necessarily associated with an exponential increase in the cost of maintaining relationships with all other group members which rapidly becomes prohibitive. As a result, the expensive and highly-valued relationships characteristic of mobile hunter-gatherer groups must inevitably become increasingly supplemented with cheaper and less highly valued 'weak ties' (Granovetter 1973, 1983). This creates extra 'levels' in the hierarchy of social relationships which are added on top of the 'intimate' circle of approximately five kin relations and/or intimate friends; the 'sympathy group' of approximately fifteen wider family and friends; the approximately fifty individual-strong 'band' of wider associates and the approximately 150-strong strong 'active network' characteristic of traditional societies (Gamble 1999: 59–60). These groupings remain a significant building block for contemporary western humans (Dunbar 1993: 684–6, Tables 11.1 and 11.2; Zhou et al. 2005). However, the social networks of many modern humans incorporate much higher levels of this hierarchy, from the 'global network' level of approximately 400 (Gamble 1999: 59–60) to the tens of millions 'following' individual celebrities on social network sites. At each level, the number of nodes to which one is connected increases, but emotional engagement and personal input in each one decreases (Roberts et al. 2009), so that at higher levels, many individual relationships are simplified and highly contextual, confined to a relatively restricted part of an individual's broader network (Lofland 1973; Milgram 1977; Whitelaw 1991: 153; Kudo and Dunbar 2001).

It is the 'weak ties' characterizing these higher levels of individuals' social networks that are fundamental to linking up the densely connected and largely kin-defined intimate networks that are our primate heritage, biasing social systems from processes of fission—which keeps mobile and traditional societies small-scale—towards increasing fusion (Zhou et al. 2005; Onnela et al. 2011: 4). Thus the growth of social groups, ultimately resulting in larger-scale, sedentary, and urban societies, is not simply the result of increasing numbers but also involves structural changes in individuals' and groups' social networks as larger-scale, less dense networks are constructed which incorporate the smaller and more 'intimate' social groupings characteristic of small-scale societies.

**Table 11.1.** Matrix of great-circle distances in km between sites dated to 18–17kyr cal BC. Site codes: EGI3/4 = Ein Gev I level 3/4; H2 = Haon 2; HamIV = Hamifgash IV; KIVD = Kharaneh IV level D; Md = Mdamagh; NOTK = Nahal Oren Terrace XVII/IX (Noy); OII = Ohalo II; RC = Rakefet Cave XIII; UeR = Urkhan e-Rubb IIa; WH31 = Wadi Hammeh 31; Whs1065 = Wadi Hasa 1065 B-E; WJ6A = Wadi Jilat 6 Upper Phase A

| | EGI3 | EGI4 | H2 | HamIV | KIVD | Md | NOTK | OII | RC | UeR | WH31 | Whs1065 | WJ6A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EGI3** | – | 0.00 | 9.33 | 205.50 | 139.82 | 271.91 | 65.14 | 7.91 | 58.25 | 83.76 | 37.99 | 208.11 | 160.30 |
| **EGI4** | 0.00 | – | 9.33 | 205.50 | 139.82 | 271.91 | 65.14 | 7.91 | 58.25 | 83.76 | 37.99 | 208.11 | 160.30 |
| **H2** | 9.33 | 9.33 | – | 196.40 | 134.05 | 262.86 | 61.75 | 5.81 | 53.76 | 74.45 | 28.93 | 199.36 | 153.75 |
| **HamIV** | 205.50 | 205.50 | 196.40 | – | 187.62 | 124.85 | 173.86 | 198.43 | 169.37 | 126.70 | 171.50 | 114.22 | 177.40 |
| **KIVD** | 139.82 | 139.82 | 134.05 | 187.62 | – | 180.12 | 177.54 | 139.85 | 166.79 | 103.05 | 112.57 | 112.52 | 25.85 |
| **Md** | 271.91 | 271.91 | 262.86 | 124.85 | 180.12 | – | 266.66 | 267.11 | 258.68 | 190.16 | 233.94 | 68.81 | 156.73 |
| **NOTK** | 65.14 | 65.14 | 61.75 | 173.86 | 177.54 | 266.66 | – | 58.17 | 10.75 | 84.69 | 67.42 | 212.24 | 191.71 |
| **OII** | 7.91 | 7.91 | 5.81 | 198.43 | 139.85 | 267.11 | 58.17 | – | 50.82 | 78.01 | 33.48 | 204.05 | 159.46 |
| **RC** | 58.25 | 58.25 | 53.76 | 169.37 | 166.79 | 258.68 | 10.75 | 50.82 | – | 74.69 | 57.00 | 203.12 | 181.03 |
| **UeR** | 83.76 | 83.76 | 74.45 | 126.70 | 103.05 | 190.16 | 84.69 | 78.01 | 74.69 | – | 46.55 | 130.13 | 111.62 |
| **WH31** | 37.99 | 37.99 | 28.93 | 171.50 | 112.57 | 233.94 | 67.42 | 33.48 | 57.00 | 46.55 | – | 170.57 | 129.82 |
| **Whs1065** | 208.11 | 208.11 | 199.36 | 114.22 | 112.52 | 68.81 | 212.24 | 204.05 | 203.12 | 130.13 | 170.57 | – | 90.66 |
| **WJ6A** | 160.30 | 160.30 | 153.75 | 177.40 | 25.85 | 156.73 | 191.71 | 159.46 | 181.03 | 111.62 | 129.82 | 90.66 | – |

**Table 11.2.** Results of Shapiro-Wilks tests of distributions of the great-circle distance, GIS-derived cost of travel and material culture matrices. Low values of W indicate positive skew. * indicates result is significant at the 0.05 level; ** that it is significant at the 0.01 level

| | Great-circle distance (GCD) matrix | | GIS-derived cost of travel (GISCT) matrix | | Material culture matrix | |
|---|---|---|---|---|---|---|
| Timeslice (kyr cal BC) | W | P | W | P | W | P |
| **>21** | 0.73 | 0.021* | 0.95 | 0.722 | 0.94 | 0.683 |
| **21–20** | 0.6 | 0.000** | 0.85 | 0.161 | 0.99 | 0.995 |
| **20–19** | 0.65 | 0.002* | 0.59 | 0.001** | 0.83 | 0.131 |
| **19–18** | 0.58 | 0.000** | 0.9 | 0.370 | 0.82 | 0.085 |
| **18–17** | 0.37 | <0.0001** | 0.8 | 0.006** | 0.87 | 0.055 |
| **17–16** | 0.45 | <0.0001** | 0.64 | <0.0001** | 0.94 | 0.546 |
| **16–15** | 0.57 | <0.0001** | 0.63 | <0.0001** | 0.9 | 0.327 |
| **15–14** | 0.33 | <0.0001** | 0.04 | <0.0001** | 0.91 | 0.118 |
| **14–13** | 0.31 | <0.0001** | 0.52 | <0.0001** | 0.93 | 0.183 |
| **13–12** | 0.33 | <0.0001** | 0.65 | <0.0001** | 0.95 | 0.479 |
| **12–11** | 0.29 | <0.0001** | 0.8 | 0.001** | 0.94 | 0.226 |
| **11–10** | 0.17 | <0.0001** | 0.78 | <0.0001** | 0.96 | 0.105 |
| **10–9** | 0.14 | <0.0001** | 0.83 | <0.0001** | 0.98 | 0.415 |
| **9–8** | 0.13 | <0.0001** | 0.88 | <0.0001** | 0.98 | 0.227 |
| **8–7** | 0.13 | <0.0001** | 0.84 | <0.0001** | 0.98 | 0.227 |
| **7–6** | 0.19 | <0.0001** | 0.89 | 0.002** | 0.97 | 0.393 |

## 11.3 GROUNDING THE NET: THE GEOGRAPHICAL AND SOCIAL NETWORKS OF THE NEAR-EASTERN EPIPALAEOLITHIC AND EARLY NEOLITHIC

SNA thus provides an extremely useful framework for investigating social change archaeologically. However, the practicalities of applying SNA to archaeological data are still very much in the process of being thrashed out, and one particular aspect of concern is the rather abstracted nature of the networks discussed above from any kind of real-world geographic context. Network analysis in other disciplines has long recognized the significance of geography and spatial distance on connectivity. In spatial networks such as power grids, transport systems, and neural connectivity, the probability of a link between any two nodes is known to decrease proportionally to the geographic distance between them because of the higher costs associated with longer-range connections (see e.g. references in Backstrom et al. 2010: 62; Expert et al. 2010). Even in archaeology, the analysis of distance decay of raw material and material culture from its source (sometimes known as ‘fall-off analysis’) has been used to identify particular trade structures and institutions (see e.g. Renfrew et al. 1968; Hodder 1974; Renfrew and Dixon 1976 for further discussion).

However, the significance of geography in the establishment and evolution of networks has rarely been recognized in *social* network approaches, although there are strong intuitive reasons to believe it may be a significant factor. For example, in human social networks, increasing geographic distance between individuals necessarily means they are less likely to encounter one another and thereby establish or maintain a significant relationship. In modern contexts, geographic distance may perhaps be expected to be less of a constraint on the formation of a social relationship. Networks supported by the use of technologies such as landlines and, latterly, mobile phones and the internet, which significantly reduce the cost of communication over large geographic distances, might perhaps be expected to be less influenced by geographical factors. Nevertheless, declarations of the 'end of geography' (Graham 1998) or the 'death of distance' (Cairncross 2001) have more recently been challenged by a number of studies suggesting that geographical factors remain significant even in the formation of purely online social networks, such that the probability of any two nodes sharing a tie is inversely related to their geographic distance (with the rate of decay described by a power law of the form $P(d) \sim d^{-\alpha}$, the value of $\alpha$ ranging between 0.5 and 2; see references in Liben-Nowell et al. 2005; Lambiotte et al. 2008; Backstrom et al. 2010; Onnela et al. 2011; Scellato et al. 2011). In pre-literate networks, where even ideas and concepts are necessarily transported in embodied or materialized form, geographical 'friction' can thus be expected to have a significant effect.

Indeed, the influence of geographical proximity on social network structure is of particular interest during the Epipalaeolithic and early Neolithic. In small-scale societies, social space is often largely coextensive with geographical space (Lofland 1973; Whitelaw 1991), as patterns of social interaction are organized primarily around kinship and close physical proximity (Wilson 1988; Whitelaw 1991). Such groups tend to be dense and tightly 'clustered' (i.e. with a high degree of 'transitive' relationships in which, if A is linked to B and C, there is a very high probability that B and C will also be linked; however, none of the three may be connected to any nodes outside these dense clusters). Tellingly, Watts has described this kind of network as a 'caveman' world (2003: 74–8). However, as noted above, the scaling-up of a social network necessarily requires increasing proportions of 'weak links'. While many relationships in larger societies are of course still based on kinship and/or geographical proximity (e.g. next-door neighbours, school or university friends, work colleagues at neighbouring desks), other forms of relationship may also be 'layered on' to these which may be almost completely *trans*-spatial (e.g. geographically remote colleagues working in the same field, people with shared interests, Liben-Nowell et al. 2005: 5). Just as weak links connect dense clusters into wider systems—the definition of a 'small-world' social system—geographically extended trans-spatial relationships connect dense local groups of individuals or sites into regional-scale social networks.

There is some independent evidence to suggest that such trans-spatial relationships may have become more significant during this period. Specialization of occupation—a major source of 'weak ties' in modern societies (Granovetter 1973, 1983)—seems to have formed an increasingly significant part of early Neolithic life. Specialization in activities such as the preparation of string or cord is inferred for Tell Abu Hureyra (Moore and Molleson 2000: 503; Molleson 2007: 193) while the specialized manufacture of jewellery is identified elsewhere in the Middle and Late PPNB (Mahasneh 2003; Wright and Garrard 2003: 272; Rollefson 2005; Gebel and Kinzel 2007), and perhaps even earlier (Kuijt and Mahasneh 1998; Reese 1991). The appearance of specialists in manufacture and trade may have been a significant mechanism by which more geographically distant connections were forged between individuals and groups.

The development of such long-range connections is likely to be hugely affected by spatial distance and the relative ease of travel through different kinds of terrain and habitat. Furthermore, ecological and environmental factors will necessarily impact on the time and energy available for engaging in different forms of social interaction (e.g. Lehmann et al. 2008), and on the ecological costs and benefits of large-scale versus local relations and trade between groups (Gamble 1983; Knappett et al. 2008: 1011). The Near East is characterized by considerable variation in terrain and habitat types, from the steppes and grasslands and scattered woodlands of the northerly, upland regions of the Taurus and Zagros and some parts of the Levant, to full desert over relatively short geographic distances (Ramankutty and Foley 1999; Chataigner and Barge 2007). Such geographical and ecological patterning can be expected to have had a significant impact on the development of regional-scale networks of distribution and dissemination of material culture and social practices.

Here I attempt to 'ground' the networks presented above by considering the interaction between materiality and geography at the regional scale for each 1,000-year timeslice throughout the Epipalaeolithic and early Neolithic. Networks derived using two different measures of geographic distance and ease of movement between sites/nodes are compared with those derived from material culture measures of interaction to try and tease out some preliminary details of the interplay between socio-material and geographic relations.

## 11.4 THE DATASETS

### 11.4.1 Distance-Derived Networks 1: 'As The Crow Flies' Great-Circle Distance

Matrices of the 'straight-line' geodesic great-circle distance (GCD; the shortest 'as the crow flies' spatial distance between any two points on the surface of a

sphere) in km between each pair of sites in each 1,000-year timeslice were compiled (e.g. Table 11.1).

As expected, the distributions of these GCD matrices were highly positively skewed, demonstrating significant kurtosis or a 'fat-tailed' distribution in which most sites were relatively short geographic distances from most others, with increasingly fewer long-distance connections (though still significantly more than would be the case for a normal distribution). Shapiro-Wilks tests conducted on these matrices confirmed that, in contrast to those derived from material culture, distributions differed significantly from normal distributions (results are presented in Table 11.2). As the data are inherently positive, with values approaching zero, these matrices were $\log^{10}$ transformed to create normal distributions which could be statistically compared with those of the material culture networks (Shennan 1997: 94).

### 11.4.2 Distance-Derived Networks 2: GIS-Derived Cost of Travel

Straight-line, 'as the crow flies' distances provide a good preliminary guide to the costs of movement between sites. However, they remain a rather unsophisticated measure: the 423 km between M'lefaat and Ganj Dareh Tepe, involving considerable elevation changes, clearly presents a rather different set of challenges than the only slightly greater distance (548 km) between M'lefaat and Ali Kosh—a relatively gentle excursion along the Tigris, while the 1,145 km between Beidha and Ali Kosh, straight across the desert (Fig. 11.1), presents still different problems.

In order to address this, a GIS model of the region was constructed using the open-source GRASS GIS (<http://grass.fbk.eu/>). A digital elevation model (DEM) of elevation for the region was obtained from the Shuttle Radar Topography Mission (SRTM) dataset (<http://srtm.csi.cgiar.org/>), accurate to three arc-seconds (or ~90m at the Equator). Georeferenced maps of rivers and water bodies were downloaded from Natural Earth (<http://www.naturalearthdata.com/downloads/110m-physical-vectors/>) at a scale of 1:110 m and edited to remove such historical additions as the numerous dams and lakes along the course of the Euphrates in Turkey and Syria. These maps were then combined to provide a basic model of the region's (modern) geography (Fig. 11.1) which was then used as the basis for deriving a cost-surface at a resolution of six arc-minutes (~3.4 km$^2$ at the equator, in order to speed up processing time) specifying the ease or difficulty of traversing each 'cell' of data.

Costs of movement overland are solely predicated on the assumption of movement by foot, as there is no evidence of the use of domesticated animals for traction or transport during this period. The 'secondary products revolution' during which the use of animals for traction developed occurred later, during the 4th–3rd millennium (Sherratt 1981). The development of the wheel

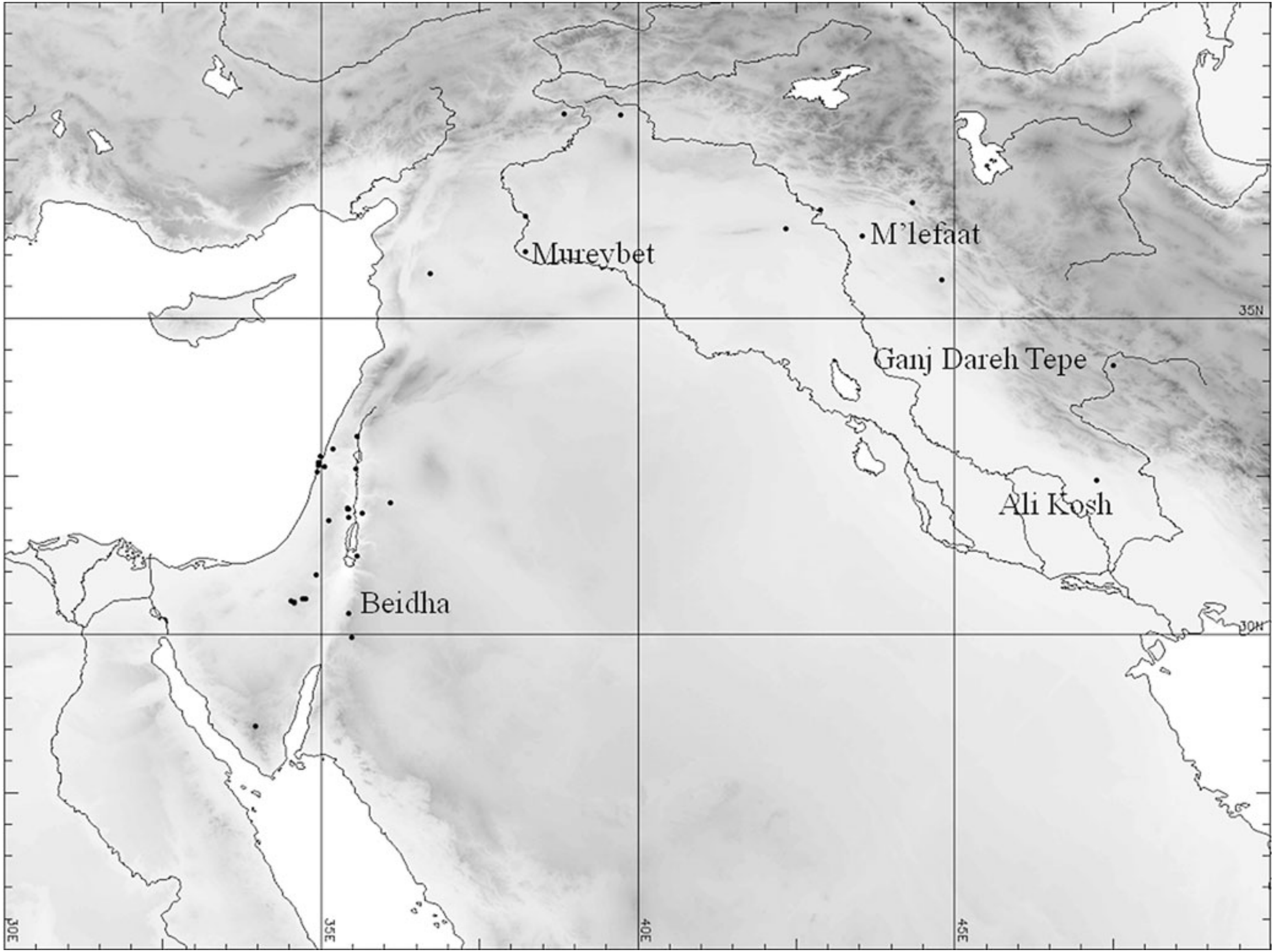


**Fig. 11.1.** DEM showing sites dating to 11–10 kyrs cal BC; darker colours indicate higher elevation. Only sites named in the text are labelled.

occurred after 4000 BCE (Anthony 2010: 65) and the domestication of horses is currently thought to have taken place in the Caucasus around 3500 BCE (e.g. Outram et al. 2009), well after the period under consideration here.

Calculation of the cost of movement overland is primarily derived from the physiological costs associated with movement over different gradients of topographic slope (Diez (cited by Leusen 1999: 217)) as modified by Bell and Lock (2000: 88; see discussion and references in Coward 2005: 221), such that cost = (*tan* per cent slope)/*tan* 1 (see e.g. Coward 2005: 221 for further discussion) was thus used to generate the cost surface from the slope layer derived from the original DEM.

The cost assigned to water bodies and the sea was determined by the relative physiological energetic demands of traversing water bodies. At 'moderate' effort levels ('swimming, breaststroke, recreational'), swimming is estimated at 5.3 metabolic equivalents (METs—the average metabolic rate of a particular physical activity relative to the resting metabolic rate, such that one MET = 1kcal/kg/hour; Ainsworth et al. 2011). It is also of course possible that watercraft were used to travel along the Levant coast, or down navigable rivers such as the Tigris and Euphrates. While there is little direct evidence for the use of this mode of transport in the region at this time, boat technologies were certainly known to some human groups by even the earliest phases of this study (and indeed, arguably date as far as 60–45,000 yrs BP; see e.g. Bednarik 2003; Broodbank 2006 for review). The earliest boats are thought to have been dugouts or canoes made of skin or reeds (McGrail 2004), and were certainly in regular use by the Mesolithic at least (Mithen 1994: 106). By the 8th millennium BC obsidian was traded by boat across the Aegean (Renfrew 1975), and by the late 6th millennium a widespread trade network linked Mesopotamia and the Gulf (see e.g. Broodbank 2006; Carter 2006 for reviews). However, sailing technology is not thought to have been developed until the Bronze Age *c* 2,000 BC (Knappett et al. 2008: 1011). The energetic demands of kayaking, at 5 MET, are roughly equivalent to those of swimming (Ainsworth et al. 2011), and a relative cost of 5$\times$ base cost as calculated from the DEM was therefore assigned to all cells assigned to rivers, water bodies, and the sea.

An additional consideration for travel within the region is the challenge presented by desert environments. Travel within these areas will necessarily involve the transport of sufficient water. An average human of $\sim$87 kg needs to consume between 3.3 and 4.7 per cent body weight of water per day, depending on the climate (<http://www.csgnetwork.com/humanh2owater.html>). Thus, below the 250 mm isohyet (the ecological definition of a desert), the need to carry extra water over and above that normally carried in other habitats is equivalent to an increase in the weight being transported (and thus the energy consumed) of 1.4 per cent (the difference between the extra 3.3 per cent weight of water required in 'cool' or 'warm' conditions and the 4.7 per cent in 'extreme heat').

In order to incorporate this into the GIS, data on modern precipitation were downloaded (Hijmans et al. 2005, available from <http://www.worldclim.org>) and the region corresponding to <250 mm/yr rainfall (Fig. 11.2) extracted and assigned an additional 'friction' cost above the base cost derived from the DEM of 1.4 per cent (i.e. the elevation map was multiplied by 1.014). The resulting map was combined with the cost maps derived from elevation and the traversing of water to provide the final cost-surface used in these analyses.

The GRASS module r.cost was then used to calculate the cumulative cost of movement between each pair of sites in each timeslice (example in Fig. 10.3). The module r.walk provides a more accurate means of estimating the cost of human movement between two points; however, as r.walk takes into account the difference between ascending and descending slopes of differing gradient, this module outputs an anisotropic cost which is valid only in one direction (i.e. the cost of moving from A–B may differ from that of B–A). In contrast, r.cost outputs an isotropic cost figure, i.e. one that is valid in both directions (A–B *and* B–A). The choice of r.cost over r.walk was thus prompted by time constraints—as the cost of travel between each dyad of sites need only be computed once—and the need to compare these networks with the undirected ones derived from material culture.

The result was a raster 'cost-surface' map in which each cell was associated with a cumulative 'cost' of traversing it. Further maps of the cumulative cost of travel between each pair of sites were calculated from this, and the costs of movement between them determined (example in Table 11.3). Shapiro-Wilks tests demonstrated that GIS-derived costs of travel (GISCT) were not normally distributed, and therefore, as for the as-the-crow-flies distances discussed above, these data were also $\log^{10}$ transformed.

## 11.5 RESULTS

Pearson correlations between (logged) great-circle distance- (GCD) and GIS cost-derived (GISCT) matrices and the contemporary matrices derived from measures of material culture and material similarity were calculated for each timeslice using UCINET v6.31 (Borgatti et al. 2002). Since classic statistical tests cannot be used for social network analysis data (in which individual observations are typically not independent), association between networks is assessed using permutation. In this procedure after correlation coefficients have been calculated for each timeslice, the matrices are randomized (2,500 times in each of the below procedures) and coefficients recomputed for each permutation to determine the proportion of times the correlation between the observed and randomized geographic network exceeds that observed in the data. A low proportion of good correlations between the observed and randomized networks suggests

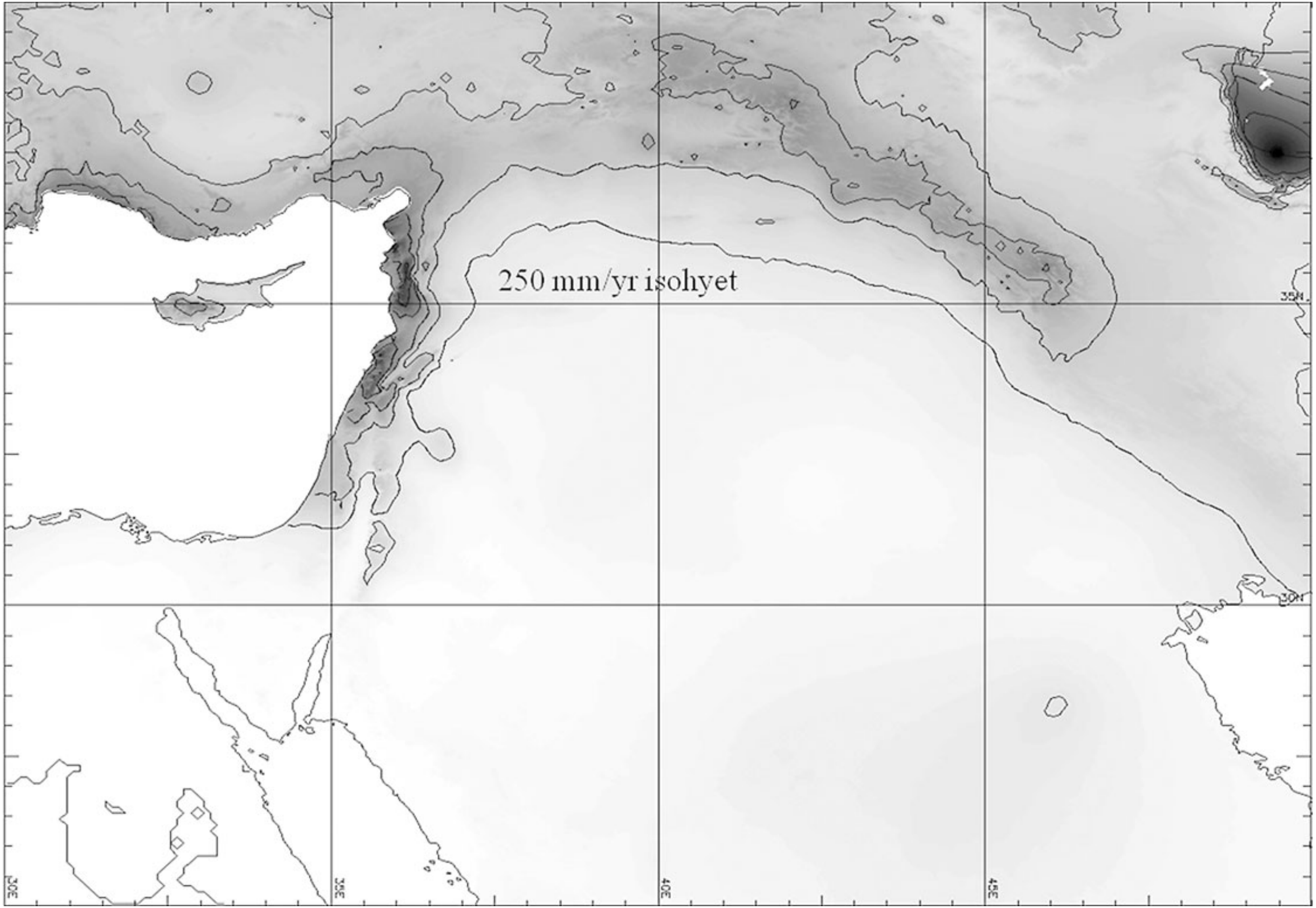


**Fig. 11.2.** Modern precipitation in the region, isohyets at 250 mm/yr intervals, 250 mm/yr isohyet labelled (source Hijmans et al. 2005).


**Fig. 11.3.** Cost surface map of the region centred on Tell Abu Hureyra. Lighter areas in the immediate vicinity of the specified site indicate a low cumulative cost as they require less effort to reach from that site than areas at a distance, whose darker colour indicate higher cumulative costs.

**Table 11.3.** Matrix of GIS cost of travel between sites dated to 18–17kyr cal BC. Site codes are given in Table 11.4

| | EGI3 | EGI4 | H2 | HamIV | KIVD | Md | NOTK | OII | RC | UeR | WH31 | Whs1065 | WJ6A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EGI3** | – | 0.00 | 0.00 | 0.00 | 31.07 | 0.00 | 36.17 | 14.00 | 33.88 | 42.95 | 0.00 | 65.88 | 43.46 |
| **EGI4** | 0.00 | – | 0.00 | 39.01 | 31.07 | 0.00 | 36.17 | 14.00 | 33.88 | 42.95 | 0.00 | 65.88 | 43.46 |
| **H2** | 0.00 | 0.00 | – | 0.00 | 44.92 | 85.03 | 0.00 | 0.00 | 0.00 | 34.76 | 17.77 | 66.20 | 50.24 |
| **HamIV** | 0.00 | 39.01 | 0.00 | – | 67.74 | 0.00 | 0.00 | 45.37 | 0.00 | 0.00 | 0.00 | 58.02 | 0.00 |
| **KIVD** | 31.07 | 31.07 | 44.92 | 67.74 | – | 50.45 | 58.54 | 37.03 | 56.25 | 31.38 | 45.69 | 32.23 | 4.55 |
| **Md** | 0.00 | 0.00 | 85.03 | 0.00 | 50.45 | – | 0.00 | 0.00 | 0.00 | 69.53 | 96.14 | 47.21 | 44.02 |
| **NOTK** | 36.17 | 36.17 | 0.00 | 0.00 | 58.54 | 0.00 | – | 27.65 | 7.32 | 0.00 | 0.00 | 72.88 | 62.01 |
| **OII** | 14.00 | 14.00 | 0.00 | 45.37 | 37.03 | 0.00 | 27.65 | – | 25.36 | 34.42 | 0.00 | 76.53 | 49.46 |
| **RC** | 33.88 | 33.88 | 0.00 | 0.00 | 56.25 | 0.00 | 7.32 | 25.36 | – | 0.00 | 0.00 | 68.43 | 60.76 |
| **UeR** | 42.95 | 42.95 | 34.76 | 0.00 | 31.38 | 69.53 | 0.00 | 34.42 | 0.00 | – | 36.40 | 46.99 | 31.27 |
| **WH31** | 0.00 | 0.00 | 17.77 | 0.00 | 45.69 | 96.14 | 0.00 | 0.00 | 0.00 | 36.40 | – | 77.31 | 48.11 |
| **Whs1065** | 65.88 | 65.88 | 66.20 | 58.02 | 32.23 | 47.21 | 72.88 | 76.53 | 68.43 | 46.99 | 77.31 | – | 28.25 |
| **WJ6A** | 43.46 | 43.46 | 50.24 | 0.00 | 4.55 | 44.02 | 62.01 | 49.46 | 60.76 | 31.27 | 48.11 | 28.25 | – |

**Table 11.4.** Pearson correlations between material culture matrix and great-circle distance and GIS-derived travel cost matrices and significance based on 2,500 permutations using UCINET v6.31's QAP routine. Low p values suggest that the similarities between the observed and model network are unlikely to be solely due to chance, i.e. that there is no significant difference between the matrices. * indicates result is significant at the 0.05 level; ** that it is significant at the 0.01 level

| | Great-circle distance (GCD) matrix | | GIS-derived cost of travel (GISCT) matrix | |
|---|---|---|---|---|
| Timeslice | Pearson Correlation | p | Pearson Correlation | p |
| **>21** | −0.05 | 0.495 | −0.508 | 0.118 |
| **21–20** | 0.15 | 0.289 | −0.016 | 0.466 |
| **20–19** | 0.454 | 0.073 | 0.368 | 0.260 |
| **19–18** | 0.478 | 0.029* | 0.228 | 0.230 |
| **18–17** | −0.285 | 0.051 | −0.353 | 0.016* |
| **17–16** | −0.261 | 0.045* | −0.289 | 0.034* |
| **16–15** | 0.055 | 0.385 | 0.080 | 0.375 |
| **15–14** | −0.104 | 0.182 | −0.123 | 0.117 |
| **14–13** | −0.131 | 0.105 | −0.070 | 0.216 |
| **13–12** | −0.254 | 0.012* | 0.927 | 0.000** |
| **12–11** | −0.036 | 0.364 | −0.067 | 0.291 |
| **11–10** | −0.010 | 0.421 | −0.125 | 0.042* |
| **10–9** | −0.076 | 0.112 | −0.086 | 0.072 |
| **9–8** | −0.106 | 0.023* | −0.117 | 0.017* |
| **8–7** | −0.124 | 0.007** | −0.142 | 0.013* |
| **7–6** | −0.057 | 0.213 | −0.112 | 0.118 |

that the similarities between the observed and model network are unlikely to be solely due to chance (Hanneman and Riddle 2005). UCINET's Quadratic Assignment Procedure (QAP) computes Pearson's correlation coefficient between corresponding cells of an observed network (here, the adjacency matrix describing material culture similarities between pairs of sites) and an expected network (the GCD and GISCT networks). Results are presented in Table 11.4, and demonstrate that only a minority of material culture networks are significantly correlated with either measure of geographic distance. Furthermore, while most correlations are, as might be expected, negative (i.e. as geographic distance and/or cost of travel between sites increases, the material culture similarities between them decrease), this is not true in all cases. Indeed, two such positive correlations between high geographic distance and similarity in material culture inventories are significant—that between GCD and material culture matrices in the 19–18kyr cal BC timeslice, and between GIS and material culture matrices in the 13–12kyr cal BC timeslice. The strong correlation of the latter matrices (with a Pearson correlation of 0.927) is also strongly statistically significant (p=<0.000).

**Table 11.5.** Results of multiple regression using degree (material culture similarity) as the dependent variable and summed great-circle distance and summed GIS-derived travel cost as the independent variables

| Timeslice (kyrs cal BC) | Correlation of GCD and GISCT | Colinearity of material culture similarity and GCD | Colinearity of material culture similarity and GISCT | $r^2$ | p |
|---|---|---|---|---|---|
| **>21** | 0.878 | 0.092 | −0.395 | 0.997 | 0.411 |
| **21–20** | 0.904 | 0.182 | 0.161 | 0.033 | 0.876 |
| **20–19** | 0.995 | 0.41 | 0.381 | 0.235 | 0.89 |
| **19–18** | 0.887 | 0.757 | 0.529 | 0.666 | 0.325 |
| **18–17** | 0.837 | −0.101 | −0.182 | 0.042 | 0.772 |
| **17–16** | 0.972 | −0.078 | −0.148 | 0.099 | 0.676 |
| **16–15** | 0.991 | 0.039 | −0.005 | 0.107 | 0.777 |
| **15–14** | 0.931 | 0.012 | 0.056 | 0.015 | 0.914 |
| **14–13** | 0.885 | −0.027 | −0.081 | 0.016 | 0.862 |
| **13–12** | 0.915 | −0.060 | −0.113 | 0.024 | 0.806 |
| **12–11** | 0.940 | 0.077 | −0.015 | 0.034 | 0.689 |
| **11–10** | 0.862 | 0.203 | 0.000 | 0.159 | 0.099 |
| **10–9** | 0.662 | −0.040 | −0.101 | 0.012 | 0.718 |
| **9–8** | 0.688 | −0.077 | −0.143 | 0.021 | 0.550 |
| **8–7** | 0.747 | −0.073 | −0.110 | 0.012 | 0.663 |
| **7–6** | 1 | −0.183 | −0.256 | 0.071 | 0.284 |

These results suggest that geographic distance is not the sole determinant of material culture similarity in most cases, and indeed that in some cases the relationship may be completely at odds with the gravity models of fall-off with geographic distance usually posited as a priori assumptions in analyses of the relationship between geographic distance and material culture dissemination (e.g. Renfrew et al. 1968; Hodder 1974; Plog 1976; Renfrew and Dixon 1976; Pires-Ferreira 2009 [1976] and other sections in Flannery 2009 [1976]) or, indeed, any form of spatial distance relationship (Expert et al. 2010).

To investigate the relationship between geographic distance and material culture similarity within these networks, multiple regressions of the GCD and GISCT measures on material culture networks were performed, with material culture similarity (degree) as the dependent variable and GCD and GISCT as the independent variables. As before, significance was assessed by 2,500 random permutations. The sum of each site's GCD from every other was calculated and regressed on the sum of each site's GIS from every other and the degree centrality of that site (the summed values of each relationship that site has with all others; i.e. the summed number of material culture elements shared with all other sites). Results are presented in Table 11.5. As expected, correlation between the two geographic distance matrices is high throughout (although the two measures do diverge in some cases, particularly in some later timeslices), but correlation between either of these measures and the

measure of material culture similarity (degree, in this case) is almost uniformly low. Again, while most of the measures of correlation are negative, indicating an inverse relationship between geographic distance and material culture similarity, this is not true in all cases. Low $r^2$ values suggest that geographic distances between sites—by either measure—are not closely related to material culture similarity. A very high $r^2$ value for the earliest timeslice is not significant, and is probably due to the small dataset. In short, it does not seem that the geographic relationship between sites, measured either by GCD or by GIS, has a significant relationship with the material culture relationship between sites.

Moran's *C* and Geary's *I* were also calculated to evaluate the autocorrelation between the network distance between actors and their material culture similarity. High measures of correlation in these statistical measures would indicate that nodes geographically closer to one another are also more likely to be those with more material culture similarities to other sites. Moran's *I* is similar to a regular correlation coefficient, evaluating the differences between each pair of sites/nodes values and the overall network mean and weighting the cross-products according to their geographic distance or the cost of travel from one another—a more 'global', network-level measure of difference. Geary's *C*, in contrast, focuses on the differences between each pair of nodes, weighted by their geographical closeness, and is thus usually considered more sensitive to local differences (Hanneman and Riddle 2005).

**Table 11.6.** Moran and Geary statistics for autocorrelation between degree (summed material culture similarity) and great-circle distance. Moran autocorrelation: –1 = a perfect negative correlation; +1 = a perfect positive correlation; 0 = no correlation. Geary autocorrelation: 1 = no association; < 1 = positive association; >1 = negative association. * indicates a result significant at the 0.05 level

| Timeslice (kyrs cal BC) | Geary | | Moran | |
|---|---|---|---|---|
| | Geary's *C* | p | Moran's *I* | p |
| **> 21** | 0.974 | 0.470 | –0.334 | 0.518 |
| **21–20** | 1.455 | 0.178 | –0.5 | 0.129 |
| **20–19** | 1.504 | 0.075 | –0.517 | 0.051 |
| **19–18** | 1.2 | 0.275 | –0.246 | 0.441 |
| **18–17** | 0.732 | 0.179 | –0.048 | 0.365 |
| **17–16** | 1.133 | 0.356 | –0.135 | 0.4 |
| **16–15** | 1.051 | 0.354 | –0.197 | 0.35 |
| **15–14** | 0.867 | 0.424 | –0.037 | 0.426 |
| **14–13** | 0.729 | 0.406 | –0.036 | 0.440 |
| **13–12** | 1.245 | 0.281 | –0.117 | 0.176 |
| **12–11** | 1.155 | 0.195 | –0.051 | 0.547 |
| **11–10** | 1.080 | 0.170 | 0.009 | 0.015* |
| **10–9** | 0.981 | 0.4 | –0.011 | 0.155 |
| **9–8** | 0.875 | 0.084 | –0.009 | 0.126 |
| **8–7** | 0.903 | 0.124 | –0.009 | 0.113 |
| **7-6** | 0.983 | 0.438 | –0.016 | 0.144 |

**Table 11.7.** Moran and Geary statistics for autocorrelation between degree (summed material culture similarity) and GIS-derived cost travel. Moran autocorrelation: −1 = a perfect negative correlation; +1 = a perfect positive correlation; 0 = no correlation. Geary autocorrelation: 1 = no association; <1 = positive association; >1 = negative association. * indicates a result significant at the 0.05 level; ** significant at the 0.01 level

| Timeslice (kyrs cal BC) | Geary | | Moran | |
|---|---|---|---|---|
| | Geary's *C* | P | Moran's *I* | p |
| **> 21** | 1.110 | 0.308 | −0.338 | 0.513 |
| **21–20** | 1.157 | 0.389 | −0.144 | 0.464 |
| **20–19** | 1.506 | 0.089 | −0.503 | 0.094 |
| **19–18** | 1.245 | 0.279 | −0.312 | 0.280 |
| **18–17** | 0.823 | 0.327 | 0.056 | 0.104 |
| **17–16** | 1.082 | 0.427 | −0.107 | 0.454 |
| **16–15** | 1.094 | 0.333 | −0.233 | 0.323 |
| **15–14** | 0.907 | 0.461 | −0.063 | 0.490 |
| **14–13** | 0.763 | 0.402 | −0.019 | 0.311 |
| **13–12** | 1.249 | 0.256 | −0.099 | 0.230 |
| **12–11** | 1.269 | 0.048* | −0.073 | 0.213 |
| **11–10** | 0.990 | 0.454 | −0.015 | 0.192 |
| **10–9** | 0.963 | 0.335 | −0.021 | 0.45 |
| **9–8** | 0.959 | 0.309 | −0.011 | 0.177 |
| **8–7** | 0.918 | 0.156 | −0.010 | 0.139 |
| **7–6** | 0.957 | 0.333 | −0.015 | 0.130 |

Results are presented in Tables 11.6 and 11.7. Low and overwhelmingly negative values of Moran's *I* (0 indicates no correlation, −1 a perfect negative correlation and +1 a perfect positive correlation) indicate that sites with high levels of material culture similarity to other sites do tend to be those closer to most other sites, but that this is a rather weak trend. Values of Geary's *C* (a value of 1 indicates no correlation, <1 a positive correlation, and >1 a negative correlation) also suggest only weak correlations, although here fully half the timeslices indicate a *positive* correlation between the two measures of geographic distance and similarity. In all cases, however, these correlations are weak. Only two results reach significance, and one of these in fact demonstrates an almost complete lack of correlation.

## 11.6 DISCUSSION

Results indicate that within each timeslice network, geographic distance, and the cost of travel between sites in fact have very little impact on the similarity

of their material culture inventories. Only in a very few timeslices were material culture networks significantly correlated with either measure of geographic distance, and in most cases these correlations were very small. Furthermore, while in the majority of timeslices the geographic distance between sites had a negative impact on their material culture similarities, in a few cases sites further apart were actually on average *more* similar. Measures of the relationship between the overall material culture similarity of each site to the rest of the network (degree—the summed values of each site's ties to all other sites in the network) and the geographical relationships between those sites support these conclusions, with values of both Moran's *I* and Geary's *C* indicating only very weak and almost exclusively non-significant correlations. Again, most of these correlations were negative, but Geary's *C* indicated the presence of a limited number of dyads within some networks in which greater geographic distances between sites was related to greater similarity in material culture. Finally, regressions of the summed GCD and GISCT of each site from every other (as proxies for the geographical relatedness of each site to the rest of the network) on the summed values of material culture similarity between them found a generally—although by no means always—negative relationship between geographic distance and material culture, but this was not statistically significant.

These somewhat unexpected results are perhaps rather counter-intuitive and even contradictory at first sight, as numerous empirical studies, both in archaeological and contemporary contexts, have identified strong relationships between geographic distance and drop-off in trade and exchange between sites (see references on p. 254), and it will be necessary to refine these analyses in order to determine how robust these results are, as the datasets may in fact contain considerable variability at much finer scales than is apparent here.

### 11.6.1 Future Refinements

One possibility is that the size of the timeslices may hide finer-grained temporal variability. A millennium may sample anything between thirty and sixty-two generations, so there remains considerable uncertainty as to whether sites in the timeslice were occupied contemporaneously. As a result, it is of course possible that considerable temporal variation is contained within them.

Geographical patterning may also be disguised or conflated in these analyses because of the inclusion of a wide range of different types and kinds of material culture and sites in each network. Not all 'things' are the same, and different kinds of material culture are likely to circulate (or indeed, not circulate) as part of different social relationships and interactions and thus

in rather different ways. For example, within these multiplex networks, some kinds of material culture may well demonstrate classic gravity-model fall-off patterns with geographic distance, while others—for example, valued or 'prestige' items—might be expected to exhibit more rapid fall-offs or, indeed, *increase* in frequency at greater geographic distances, for example if items are produced solely for trade. Further analysis of these datasets will thus focus on teasing individual networks apart to investigate potential differences in the patterns of distribution displayed by different forms of material culture and the contribution of this to network structure, for example by comparing the result of traditional fall-off analyses for the different forms of material culture incorporated in each network.

However, not all forms of social interaction are materialized, and therefore approaches based on material culture inventories will inevitably track only one aspect of the social relations that occurred between the sites in these networks. Nevertheless, the similarities in structure identified between materialized and non-materialized networks such as communication and internet networks discussed previously, and further below, suggest that while materially attested-to social relations may represent only one aspect of broader social relations, they are likely to represent impoverished versions of those wider interactions rather than being different in kind.

A more significant issue is that not only may different kinds of material culture be contributing differently to the network, but individual nodes/sites are also likely to differ. For example, more 'distant' sites are perhaps more likely to demonstrate reduced overall similarities in material culture inventories to others in the network, yet produce large quantities of another, different form of highly valued material culture which *is* traded widely throughout the network, thus at least partly compensating for its geographic distance. In tandem with the development of specialists—as discussed above—certain sites are likely to have increased in influence at the expense of others at this time ('central places'; Renfrew and Dixon 1976; Knappett et al. 2008; Flannery 2009 [1976]), thus contributing differently to overall network measure.

Further work will thus aim to incorporate independent measures of the significance of each node/site, as per traditional gravity models (Plog 1976; Knappett et al. 2008), in which the intensity of interaction between two nodes is considered to be proportional not only to the geographic distance between them but also to the 'importance' of the nodes—the assumption being that 'longer (and more expensive) ties will appear mainly between important entities, while a node will connect to an unimportant one only if they are close to one another' (Scellato et al. 2011: 8). This 'rich get richer' effect (described by Zipf's and Pareto's laws) has been noted in many social networks (Watts 2003: 105–6, 109–10).

Although 'sites' consisting solely of lithic scatters (presumably the result of ephemeral stopovers by mobile groups or more mobile components of

sedentary populations) have been removed from these datasets (see Coward 2010a for discussion), no other attempt has been made to factor in differential significance of nodes in the analyses presented here. Further investigation of the variability of the distribution of tie strength are likely to yield some interesting results in this regard, including, for example, measures of network centralization (Hanneman and Riddle 2005: section 10), or indeed simply the coefficient of variation of each site or timeslice network. However, independent data on site significance are also available for at least some sites, and could potentially be incorporated into future analyses; for example in the form of estimates of spatial extent and/or inferred population or length of occupation (despite the many problems associated with estimating such measures). Alternative possibilities might also include ecological attributes of sites, such as net primary productivity or vegetation indices of the landscape within some specified geographic distance of the village (e.g. a day's walk; Vita-Finzi and Higgs 1970).

The population density of individual sites may also be a relevant aspect here which could perhaps be factored in to analyses. Work on contemporary social networks has identified the importance of population density to network connectivity, as more tightly 'packed' settlements or populations are inherently 'dense encounter sets' (Hillier and Hanson 1984: 27) where individuals are more likely to meet by chance. However, at the same time, at higher densities, nodes are less likely to be connected to nearby individuals (since there are so many of them), and more likely to be linked to more distant nodes (Backstrom et al. 2010). In addition, when investigating such internodal variability, Liben-Nowell et al. (2005: 9) have suggested that gross distance per se may be less significant than distance *rank*; i.e. that the relevant measure should be the number of nodes closer to $x$ than $y$ rather than the distance between them. Although Backstrom et al. (2010) found that such measures did not entirely factor out the effect of differing population densities, these findings do suggest that measures of straightforward degree of betweenness centrality, as used in these analyses, might be profitably supplemented by alternative measures such as eigenvector or Bonacich betweenness, both of which provide *relative* measures of nodes' 'centrality' to social (or distance-based) networks in terms of the 'global' or overall structure of the networks (Hanneman and Riddle 2005: section 10).

### 11.6.2 Socio-Spatial Networks: Neither Entirely Social, Nor Completely Geographic

Clearly further work remains to be done on these datasets. Nevertheless, the results presented here complement recent work on contemporary social networks which emphasizes the *interplay* between geographic and social factors

in the structure of real-world social networks. Scellato et al.'s work on location-based social services, for example, identified clear structuring effects of *both* geographic distance and social topology, suggesting that real-world social networks 'can not be explained by taking into account only geographic factors or social mechanisms' (2011: 7). Similarly, Liben-Nowell et al.'s finding (2005) that while on average $\sim$69 per cent of a user's ties were explained primarily by geography, the rest were explicable in terms of a constant baseline probability of any tie being *non*-geographic in origin (P[$\sigma$] among all pairs of users $u,v \approx 5.0\times10^{-6}$; Liben-Nowell et al. 2005: 6–7). Again, they conclude that personal social networks are influenced by 'two distinct processes, one comprising all geography-dependent mechanisms (like meeting in a shared workplace), and one comprising all nongeographical processes (like meeting online through a shared interest)' (Liben-Nowell et al. 2005: 5).

However, it is notable that many of these studies on mobile and online social networks have focused purely on the probability of a tie existing at all, and not on measures of that tie's *strength*. One exception is Onnela et al.'s work on the use of location-based online services, which found that while geography was strongly associated with the existence of a tie (with the decay rate well described by a power law), tie *strength* (measured as number of calls and/or texts between any two nodes) varied only weakly with geographic distance, and measures of network betweenness centrality and geographical centrality showed no correlation (Onnela et al. 2011: 2). Furthermore, Lambiotte et al. found that the average duration of mobile calls actually *increased* with geographic distance, although this reached a plateau at around 40 km (Lambiotte et al. 2008). These studies suggest that some forms of interaction in fact act to *compensate for* increasing geographic distance: Lambiotte et al. comment that calls between people living close by are short and functional, being intended primarily to coordinate face-to-face interactions, while at longer geographic distances phone calls are a major means of maintaining relationships between individuals (Lambiotte et al. 2008: 5319; see also Hill and Dunbar 2003). These compensatory forms of interaction may well explain the relatively frequent though small correlations between the remoteness of sites and their levels of material similarity with others in the wider network, as these more distant sites work harder to maintain relations with others in the region. The kind of relatively low-cost communication evaluated in these studies is clearly not a factor for the prehistoric networks discussed here. Nevertheless, such work does indicate that, as in the analyses presented here, the structure of networks does not always correlate in any straightforward way with geographic distance or even cost of travel. It would seem that some influences on the structure of socio-spatial networks remain to be fully identified, and that different modes of interaction such as material networks, online/phone networks, and face-to-face interactions need to be compared more explicitly in contemporary contexts to ascertain the differences in structure associated

with the use of different kinds of resources and modes of interaction, and the interplay between them.

## 11.7 CONCLUSION

The analyses presented here aimed to investigate the relationships between material culture similarity—as a proxy for the strength of social relationships—between sites, and their geographical relationships over the course of a period of highly significant economic, cultural, and social change that occurred as groups became increasingly sedentary and resident in larger settlements and increasingly reliant on intensive subsistence on certain plant and animal species which ultimately became domesticated. Results suggest that within each network, the geographical relationships between sites are almost entirely unrelated to their similarity in material culture terms. In fact, while the relationship was very weakly negative in most cases, with more distant sites showing fewer similarities in material culture inventories, in some cases this pattern was in fact reversed.

These results suggest that geographic distance was not the major factor determining regional-scale relations between sites throughout this period, a finding which is very interesting in the light of the generally-held belief that in small-scale societies, the social worlds of individuals are coextensive with their spatial worlds, while in larger societies other, non-geographic forms of social relation may be layered on to these. In the analyses described here, however, there is no obvious indication that earlier, mobile hunter-and-gatherer networks are any more defined by geographical proximity than later, village-dwelling agriculturalists (although measures such as transitivity and clustering were not explicitly calculated and might prove illuminating in this regard). A number of refinements remain to be made to this model. Nevertheless, the analyses presented here do suggest that a more grounded form of social network analysis (both in contemporary and archaeological contexts) is an important step towards gaining a better understanding of the insights into social and geographical topologies of social interaction and the resources with which we construct our social networks.

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# 12

# Evaluating Adaptive Network Strategies with Geochemical Sourcing Data: A Case Study from the Kuril Islands

*Erik Gjesfjeld and S. Colby Phillips*

## 12.1 INTRODUCTION

In all parts of the world and throughout time, humans have developed strategies for dealing with the unpredictable nature of their environment, and for adapting to the conditions in their environment that change at varying scales. Optimization models derived from human behavioural ecology (HBE) propose that the behavioural decisions of low-density foragers regarding resource procurement and consumption activities are made with the ultimate goal of maintaining or increasing their fitness in an efficient manner. Establishing and maintaining inter- as well as intra-group social ties is one way that hunter-gatherer groups have adapted to living in the face of environmental unpredictability where assistance or outside resources may be required (Alexander 2000; Binford 2006; Grattan 2006; Hofman et al. 2007; Kirch 1988; Reycraft and Bawden 2000; Sheets and Grayson 1979; Torrence 1999, 2002; Whallon 1989, 2006; Wiessner 1982). The exchange of material and non-material resources provides a vehicle or mechanism for developing and maintaining these networks of social relationships.

Social network analysis (SNA) provides a body of theory and a set of techniques for visualizing and measuring sets of human relationships (such as exchange), and for evaluating the implications of those relationships (Wasserman and Faust 1994). By focusing on the relationships between social entities rather than just comparisons of entity attributes, patterns that are not immediately obvious in the data may become visible. In addition, SNA is a way to superimpose a measure of non-Cartesian social geography represented by human relationships on top of cartographic space to make comparisons between geographic and social space (Mackie 2001; Thomas 2001).

However, it is difficult to quantify and qualify social network relationships that existed in the past based on a fragmented and incomplete record of human activity, which is what the archaeological record provides. This is particularly true for small, mobile groups of people who did not leave a large impact on the landscape. In addition, the archaeological record is constantly changing; as new sites are discovered and excavated, new artefact assemblages are added to those already available for use in generating the empirical basis for reconstructing past social networks. The observed network structures that can be created with archaeological data and evaluated with node- and graph-level SNA techniques represent only a basic level of analysis of the cause, nature, and impact of relationships between humans, whether as individuals or as corporate groups.

Alternatively, new techniques for modelling social networks go beyond basic network visualization and node/graph-level measurements, and provide methods for testing the statistical significance of relationships between observed and hypothesized social network structures. This chapter focuses on the use of these methods for modelling exchange-based relationships that existed in the Kuril Islands of Far Eastern Russia in the North Pacific Ocean, where foraging groups lived for more than 4,000 years in an isolated environment prone to stochastic natural events and resource unpredictability.

## 12.2 EXCHANGE AS AN ADAPTIVE SOCIAL BEHAVIOUR

Exchange can be defined as a form of material transfer with social as well as economic properties that reflects relationships at a range of social levels (individuals, groups, societies). Early archaeological observations in Europe, Asia, Oceania, and the Americas identified the movement and transfer of materials in the past, but it was the work of historians and economic anthropologists that related trade and exchange to issues such as social complexity, distribution of resources, and wealth (Oka and Kusimba 2008). Researchers of exchange such as Malinowski (1922) and Mauss (1990) saw exchange as a way to create and strengthen relationships between people based on the socially defined and enforceable obligations of reciprocity.

The critical aspects of material exchange are fundamentally based on *information*: information about the types of materials to exchange, information about the way exchange takes place, information about the physical routes and meeting places for exchange (Smith 1999). Knowledge, ideas, and relationships are passed between individuals and groups just as physical resources are, and these immaterial resources may actually be more important than the

physical materials that are traded, in terms of what is gained by participating in an exchange network. Strategies for obtaining information will vary given the scale of information required and ability or ease of acquiring it. At a local level, individuals can use multiple methods to gain information such as obtaining it for themselves or tapping into within-group information sharing. At a regional level, individuals will have incomplete knowledge about the state of the regional environment, and must depend on information-sharing networks with regional contacts (Moore 1981). Participation in networks plays a role in helping foragers reduce the uncertainty of having incomplete information about relevant environmental or social phenomena.

Personal relationships provide a social means for circumventing the local subsistence and material resource constraints that are inherent in geographically isolated environments (Mackie 2001). These social ties also have the effect of distributing environmental risks and benefits among regional participants, providing channels of communication about environmental conditions at different spatial scales, and defining lines of fusion and fission for cycles of spatial aggregation and dispersion of human groups (Braun and Plog 1982; Whallon 1989). It is expected that some form of social network can be found on every populated physical landscape due to the unpredictability of all natural environments and the need to propagate (Anderson and Gillam 2001; Wobst 1974). Of importance to the study of hunter-gatherer networks is the scale of social integration among human groups, which will have implications for the structure of networks that are created and maintained, and the type of information that is exchanged (Fitzhugh et al. 2011).

Establishing and maintaining inter- as well as intra-group social ties can be viewed as a form of optimal adaptive behaviour in terms of mitigating the risks associated with environmental unpredictability. In more formal biological terms, the development and maintenance of social networks through exchange interaction between individuals is an adaptive trait that has the potential to increase the fitness of the individuals participating in the network (Hill 2009). Such networks should then be a prerequisite for colonizing and maintaining a long-term presence in insular and unpredictable environments, enabling a form of adaptive flexibility to deal with events that cause environmental and/or social uncertainties (Fitzhugh 2004; Kirch 1988). However, network participation may also place constraints on individuals or groups in the form of social obligations that must be honoured and maintained, since human relationships are not static entities but are dynamic connections that are constantly being negotiated. The concept of exchange among hunter-gatherers becomes more interesting not only as an optimal behavioural strategy for procuring material resources, but also because participation in exchange relationships can be linked to more anthropological issues of human interaction such as territoriality, cultural transmission, and social integration over long distances.

## 12.3 SOCIAL NETWORK ANALYSIS

Social network analysis (SNA) is a systematic approach that utilizes empirical datasets, mathematical and statistical models, and visualization to explore network structure and the effects of that structure on participants in a network (Freeman 2004; Mizruchi and Marquis 2006). Social network analysis focuses on *actors* and their social *ties*: actors are defined as network nodes representing individuals, communities, corporations, nations, etc., which are linked by network ties based on communication, economic transactions, kinship, etc. (Thompson 2003). Where conventional analysis of social science data compares actors based on their attributes, SNA compares actors based on their relationships (Hanneman and Riddle 2005). The SNA perspective views actors and their behaviour as interdependent, with ties between actors acting as channels for the flow of resources (material and immaterial). Network ties both enable and constrain actor behaviour, and network structure is seen as the 'enduring pattern of actor relationships' (Freeman 2004).

Social network analysis was pioneered in sociology and social psychology, but was also implemented in anthropology as early as the 1950s by J. A. Barnes (1954) and his studies of Norwegian church parish social classes (Wasserman and Faust 1994). Within archaeology the use of SNA is not well known, but over the last several decades a number of archaeologists have begun to apply network structure and analysis methods to archaeological datasets, particularly in coastal and island regions. Hage and Harary (1991) examined network structure in their study of Oceanic exchange systems, and Hunt (1991) compared measures of island/site network position to explore models of Lapita culture exchange and communication networks across Western Polynesia, the Solomon Islands, and the Bismarck Archipelago. Also in the Pacific, Terrell (1976, 1986, 2010) has studied the impact of geographic distance on human interaction based on material culture and language groups along the Sepik Coast of Papau New Guinea, and on Pacific Islander genetic structure in Melanesia. In southern Europe, Knappett et al. (2008) generated optimization models for Bronze Age maritime-interaction networks among islands in the Aegean Sea.

Important to SNA is the idea that a network is not a metaphor for human interaction. It is a precise mathematical construct that is used to represent, analyse, and model those interactions which, for this study, are viewed as relevant to the ability of hunter-gatherer groups to survive and thrive in the Kuril Islands. Analytically, this technique provides a tool for measuring the characteristics of regional systems quantitatively, and in turn, for objectively comparing social systems with one another. Because networks are dynamic, and the types of interactions that produce network ties may shift over time, it is necessary to incorporate a diachronic element to the analysis and comparison of network structures (Neitzel 2000).

### 12.3.1 Structuralist and Individualistic Approaches to SNA

SNA approaches the study of networks from both the *structuralist* and the *individualistic* perspectives. The structuralist perspective focuses on the description and analysis of the larger network and all of its components, including the actors, their ties, and the patterns of relationships that are present in the network. The structuralist perspective ignores the agency of individual actors and is concerned with elucidating the structures of relationships within which the actors and their actions are embedded (Kilduff and Tsai 2003).

The most basic structural property measurement of a network is graph *density*. Density is a measure of the number of connections between actors in a network given the total number of possible connections. An analogy to graph density is that of a piece of woven fabric; the density represents how tightly the fibres are woven together. If all possible network connections are present in a network, it is described as a complete graph; conversely if no connections are present, it is an empty graph.

The individualistic perspective focuses on measuring the role and position of individual actors in a network. The actor may be an individual person, or an aggregation of individuals in some corporate organization; in either case, the methods and techniques of network analysis are applied in the same way. Social network studies assume that basic network principles, such as homophily, apply equally to individual people and large organizations.

Actor-level indices (also called node-level indices) measure the properties of an actors' position in the network as a way to describe the variability of the actors. Actor *centrality* measures are the most prominent node-level indices. Actors that are measured as being more 'central' in one way or another are perceived to have differential access to information or resources, and may have differential control over the flow of those resources through the network and between other actors (Freeman et al. 1991; Hanneman and Riddle 2005). There are several different types of centrality measures. *Degree* centrality measures the number of ties that an individual actor has to other actors, and is a measure of the actor's level of participation in the network. *Betweenness* centrality is a measure of the actor's position between third-party actors, and is related to an actor potentially being a bridge between two subgroups of actors and participating as a broker of information or resources between groups of actors. *Closeness* centrality measures how close an actor is to other actors and is measured by the shortest path distance between actors. *Eigenvector* centrality summarizes the other measures of individual centrality and reflects an actor's overall position within the network taking into account the degree measure of all the other nodes; higher scores are indicative of a more central position (Mizoguchi 2009). Social network theory assumes that the structure of a network impacts the behaviour of its actors, and centrality measures

provide a key metric for identifying and quantifying the most important actors in a network based on their position and distance to other actors (Mizruchi and Marquis 2006; Wasserman and Faust 1994).

### 12.3.2 Network Testing and Modelling

In addition to describing network structures and the centrality of actors within networks, SNA provides several methods for statistically testing network hypotheses and for modelling the processes that lead to a network's particular configuration and allow for the prediction of structured relationships. Null hypothesis testing provides a way to compare observed properties of a network against properties obtained from a distribution of randomly generated networks using a baseline model (Butts 2008a). The conditioned uniform graph (CUG) test procedure is one of the most useful for detecting structural biases in networks. The CUG test utilizes a baseline model of random social structure given some set of fixed constraints, such as the size of the network (number of actors), or density of the network (proportion of ties among actors present), which acts as the null hypothesis (Butts 2008b). A statistic from the observed network is compared against a distribution of values generated by the baseline model to determine if the observed statistic is significantly different from the random distribution. This is an initial step used to isolate bias in the network structure which can be used to model the stochastic processes that generated the network (Robins et al. 2007).

In contrast to testing observed network structures against random network distributions, network regression tests allow for testing the level of association between two networks. In other words, network regression seeks to test how well one network predicts another network given the same number of actors/nodes. This is accomplished by regressing each actor in a dependent network with each actor in the independent network. In order to estimate the standard R-square values and the regression coefficients used for hypothesis testing, a quadratic assignment procedure (QAP test) is utilized. In general, the process works by running 1,000 trials where the rows and columns of the dependent network are randomly shuffled while recovering the R-square and regression coefficients of these runs (Hanneman and Riddle 2005). These values are used to assemble a sampling distribution with which to estimate the association of the two networks under the null hypothesis of no association (Hanneman and Riddle 2005).

Network testing and modelling approaches to social network analysis, such as the CUG and network regression tests, have great potential for use in archaeological research. Based upon anthropological and ethnographic research such as Wiessner's (1982) study of the *hxaro* trading system, archaeologists can develop a variety of network models that can be statistically

evaluated against networks developed from archaeological research such as artefact distributions derived from geochemical sourcing data.

## 12.4 THE KURIL ISLANDS

The Kuril Islands are an appropriate place to explore the limits of human adaptive behaviour through exchange-based social networks—not in the sense of treating the islands as pristine laboratories (the Kuril archipelago is remote and sparsely populated but is not untouched by modern human activity), but because the environmental and ecological conditions that could affect humans are so apparent there.

Stretching between the northern Japanese island of Hokkaido and the southern tip of the Russian Kamchatka peninsula, the Kuril archipelago is composed of thirty-two islands of varying size, environmental and ecological diversity, and primary productivity (Fig. 12.1). The islands at the southern and northern ends of the chain tend to be larger (up to 3,200 $km^2$ in area) and more productive and biologically diverse, while the centrally located islands are small (as small as 5 $km^2$ in area) and lie in a zone of lower primary productivity. The islands are separated by a number of straits between the Sea of Okhotsk and the North Pacific Ocean, several of which are over 70 km wide and may have, at times, represented significant barriers to the movement of people through the island chain.

The Kuril Islands lie along the tectonically active Greater Kuril Trench, which generates volcanic eruptions, submarine earthquakes, and tsunamis (MacInnes et al. 2009; Melekestsev 2009). These events occur stochastically but frequently today, and analysis of geological deposits from across the islands indicates that they were not uncommon in the past (MacInnes et al. 2009). The climate of the Kuril Islands is strongly affected by water currents in the North Pacific Ocean and the Sea of Okhotsk and by the weather patterns of continental north-east Asia, and can be generally characterized as severe and unpredictable. Winters are cold with heavy snow; summers are cool with dense fog that surrounds the islands.

While the Kuril Islands represent a geographically isolated and tectonically dynamic environment that would have posed a number of challenges to human colonizers, they also provided a rich subsistence base for human groups with the appropriate adaptations. Marine resources such as sea mammals, sea birds, and fish are abundant in the islands and would have been a significant draw for people to the region. The distribution of subsistence and material resources is highly heterogeneous across the island chain, requiring a variety of adaptive strategies and behaviours depending on the specific mix of island environmental and biological diversity and productivity.

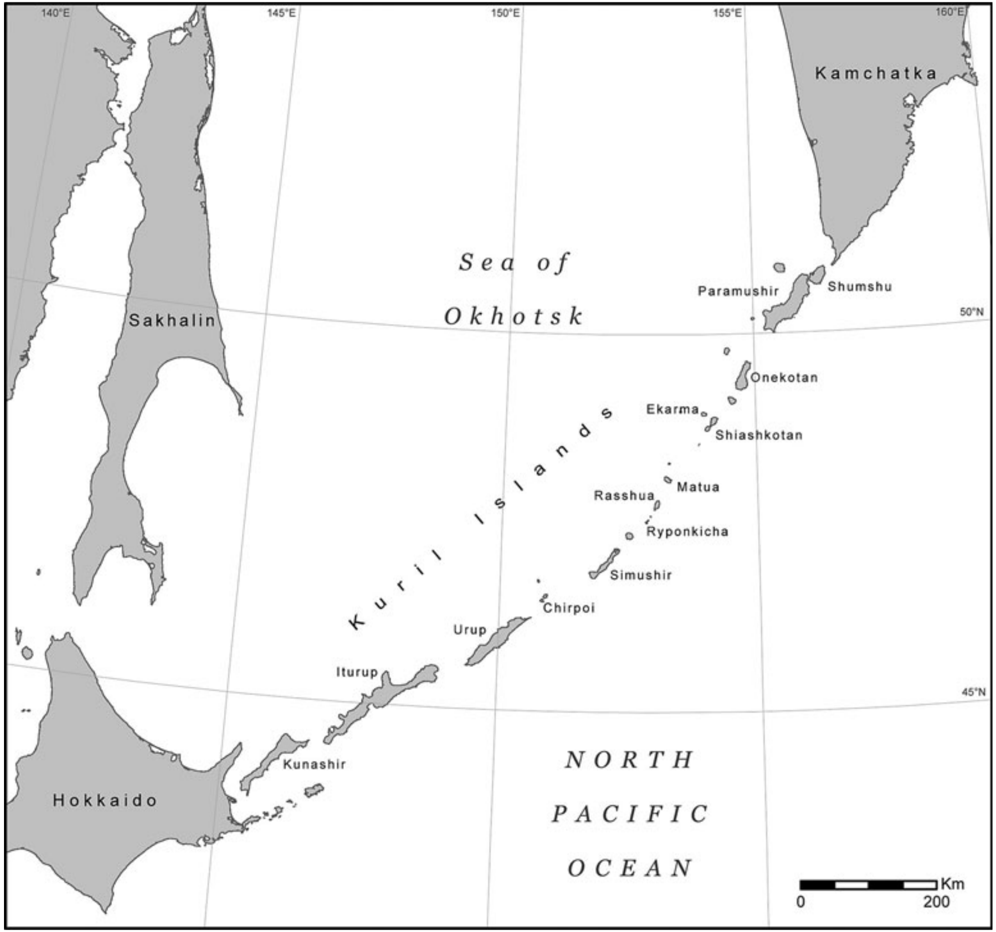


**Fig. 12.1.** Map of the Kuril Islands. Map created by A. Freeburg.

The earliest inhabitants of the Kuril Islands are likely closely related to the Jomon groups that lived throughout the Japanese islands *c.*13,000 to 2900 BP (Aikens and Higuchi 1982). The presence of people in the southern Kurils during the Early Jomon period is not unexpected given their geographical proximity and environmental similarity to Hokkaido. Several archaeological sites in the southern Kuril Islands have been assigned to the Early Jomon based on cord-marked ceramic designs and microblade lithic tools that are present in Hokkaido at this time (Vasilevsky and Shubina 2006). Concentrated migrations into the Southern and Central Kurils began with the northern movement of Epi-Jomon groups around 2900 BP. The Epi-Jomon of Hokkaido represent the last remnants of the Jomon hunter-gatherers who were ultimately displaced by wet rice agriculturalists from mainland East Asia. Epi-Jomon pottery sites are distinguished by characteristic pottery that demonstrates a conical deep-bowl form similar to earlier Jomon ceramics and retaining the cord-marked and incised patterns that were long out of use on pottery from mainland Japan (Imamura 1996). Pottery designated as Epi-Jomon has been recovered in the Kuril Islands as far north as Shiashkotan Island, and generally dates to a period of time between 2900 to 1400 BP (Gjesfjeld 2010).

By 1400 BP, the Epi-Jomon had been replaced in the Kuril Islands by the Okhotsk culture group, a highly marine-adapted population with origins in the Sea of Okhotsk region (Yamaura 1998). The Okhotsk people colonized the entire length of the Kuril archipelago up to the northernmost island of Shumshu between 1400 to 800 BP, and likely interacted with populations and culture groups inhabiting southern Kamchatka at this time. Pottery made by the Okhotsk is sand-tempered and low-fired with flat to rounded vessel bottoms, and appears to share many traits with pottery found along the Amur River on the Far Eastern Russia mainland. Stylistically, Okhotsk pottery is often undecorated with a pronounced neck and shoulder making it distinctive from the conial form and cord-marked decorations identified on Epi-Jomon ceramics.

Initial research on Epi-Jomon and Okhotsk social networks in the Kuril Islands was based on the inferred trade/exchange of obsidian stone tool raw material (Phillips 2011). While obsidian artefacts are found throughout the Kuril archipelago, obsidian does not occur naturally in the island chain. The source provenance analysis of obsidian flake debitage recovered from Kuril Island archaeological sites demonstrated that obsidian was transported from geological sources in Hokkaido and Kamchatka and distributed extensively across the islands (Phillips 2010, 2011; Phillips and Speakman 2009). This finding suggests long-distance social networks that provided access to material resources and also likely information, potential marriage partners, and reciprocal relationships that could have acted as social safety nets in the case of severe environmental perturbations, existed in the Kuril Islands during the Epi-Jomon and Okhotsk periods (Phillips 2011). It is inferred that the formation and maintenance of these

social network relationships were an important adaptive strategy for long-term success in colonizing and occupying the Kuril archipelago, particularly in the Central Kuril Islands, which are more geographically isolated, less ecologically diverse, and where subsistence resources are less predictable.

## 12.5 ANALYSING NETWORK STRUCTURES: A CASE STUDY USING KURIL ISLAND CERAMICS

Previous research on Kuril Island obsidian procurement established that social relationships existed in the island chain as a means to access nonlocal material resources. However, because obsidian entered the Kuril Islands from source areas outside of the island chain, the obsidian data is more relevant to the network relationships located at the ends of the archipelago, and is less informative about the exchange relationships among sites within the island chain. For the present case study, ceramic artefacts provide an archaeological dataset that allows for the evaluation of network relationships *within* the Kuril Islands. Intra-regional network relationships are inferred because the significant majority of ceramics were produced from materials native to the islands and used within the island chain (Gjesfjeld 2010). Tracing ceramic artefacts to their clay sources and inferred locations of production provides a measure of the distance and direction of the trade/exchange of pottery between Kuril Island sites, and also provides a mechanism for establishing network ties between archaeological sites. This focus on ties between sites is important in the context of the role that social networks played at different points in the sequence of island colonization and occupation by Epi-Jomon and Okhotsk groups, and how the two culture groups' networks of social relationships may have differed. Therefore, unlike obsidian which characterizes long-distance, non-local relationships (Phillips 2010, 2011; Phillips and Speakman 2009), social networks derived from ceramic source data can highlight the local, supra-local and regional exchange relationships within the Kuril Island archipelago better. Without prior knowledge of the exchange relationships that might have existed among past Kuril populations, generalized models of production and exchange are used to explore the structure of these relationships. These models include local production with limited exchange, local production with reciprocal exchange, and central place production with redistribution exchange. Each of the proposed models assumes ceramic production occurs within spatially discrete areas based upon the idea that ceramic production requires at least semi-sedentary settlement to complete the labour-intensive processes of raw material gathering, vessel formation and drying, and firing (Eerkens et al. 2002).

### 12.5.1 Models of Exchange and Predicted Network Structures in the Kuril Islands

In general, this study utilizes two sets of networks to infer exchange relationships. The first is a set of hypothesized networks derived from generalized ceramic exchange models and used as a baseline of network relationships (Local Production, Reciprocity, and Central Place). The second set of networks is derived from archaeological evidence using the distribution of ceramic artefacts within geochemically defined source groups to represent ceramic exchange relationships. The combination of both sets of networks allows not only the compilation of graph- and node-level measurements but also the structural evaluation of networks using network regression permutation tests. The integration of node-level and graph-level indices with structural hypothesis testing can provide by significant benefit by utilizing robust, statistical methods to evaluate the archaeological interpretations of social network models:

**Model 1—Local production**—The distribution of ceramic artefacts in geochemical source groups is representative of the network structure and reflects direct access to clay source material and localized production. We expect most ceramic artefacts recovered from the same archaeological site to be closely related in their geochemical composition. In other words, ceramic objects are made locally, used locally and discarded locally. Visually, the network structure of this model is a series of many isolates with only a few connections (see Figs. 12.2B and 12.3B). Individual actors in a local production network should have very low node centrality values and overall network density measurement close to zero.

**Model 2—Reciprocity**—The distribution of ceramic artefacts in geochemical source groups is representative of the network structure and reflects the local production and reciprocal exchange of ceramics with geographically close neighbors. We expect most ceramic artefacts recovered from the same archaeological site to demonstrate some geochemical variability with the ranges of geochemical compositions similar to ceramic artefacts recovered at nearby sites. Visually, the network structure of the model is characterized by sites with ties to their nearest neighbours (see Figs. 12.2C and 12.3C), and returning low individual actor centrality scores and a low network density value.

**Model 3—Central place**—The distribution of ceramic artefacts in geochemical source groups is representative of the network structure and reflects the regional pooling of materials and resources for the production of ceramics in a cooperative/collaborative effort. We expect most ceramic artefacts recovered from multiple sites to maintain geochemical similarity. In other words, ceramics are manufactured either by one group or by multiple cooperative groups in with exchange of ceramic objects between smaller populations. Visually, the network structure of this model is highly interconnected with each site maintaining ties with numerous other sites (see Figs. 12.2D and

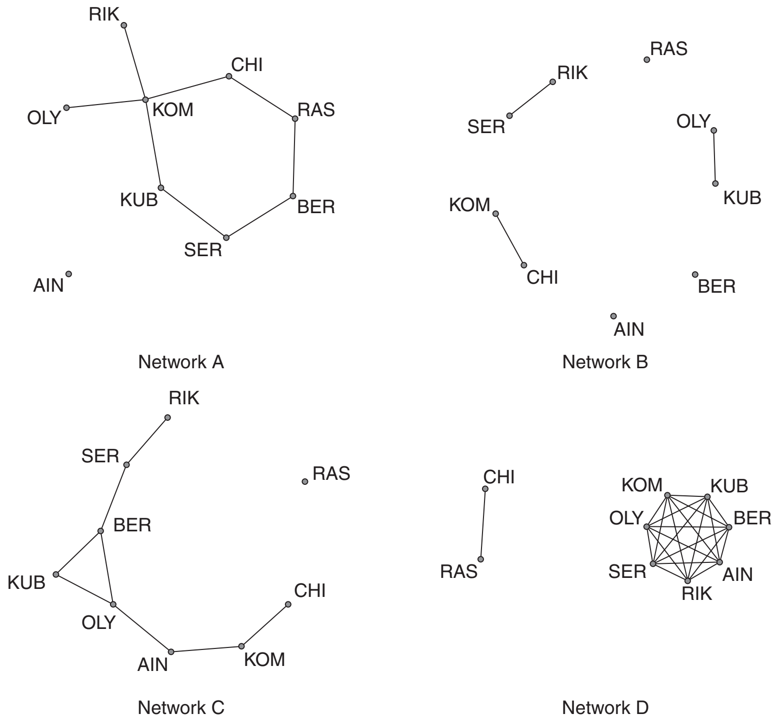


**Fig. 12.2.** Network of relationships for the Epi-Jomon cultural period. A: Observed ceramic exchange network derived from source provenance analysis; B: Local production exchange network model; C: Reciprocal exchange network model; D: Central place network model.

12.3D). This should result in higher actor-centrality scores and a higher overall network-density score.

In order to visualize these conceptual models as networks, we were required to set spatial parameters for each model. For the reciprocity model, exchange relationships are assumed to exist between island sites located within close geographic proximity to each other. Using estimates of daily travel derived from Turk's (2005) kayaking expedition through the archipelago, each site maintains a local exchange radius of approximately 50 km (one day's travel) with network ties drawn between sites within 50 km of each. For the reciprocity model, exchange relationships are considered to take place on more regional scale with connections drawn between sites less then 150 km away (three days of travel). For the central place model, major open-water straits act as natural biogeographic barriers and cleavage points that divide the island chain into three spatially distinct island groups. The Bussol Strait separates the southern Kuril Islands from the central Kurils, and the Kruzenstern Strait separates the central Kurils from the northern Kurils. Archaeological sites

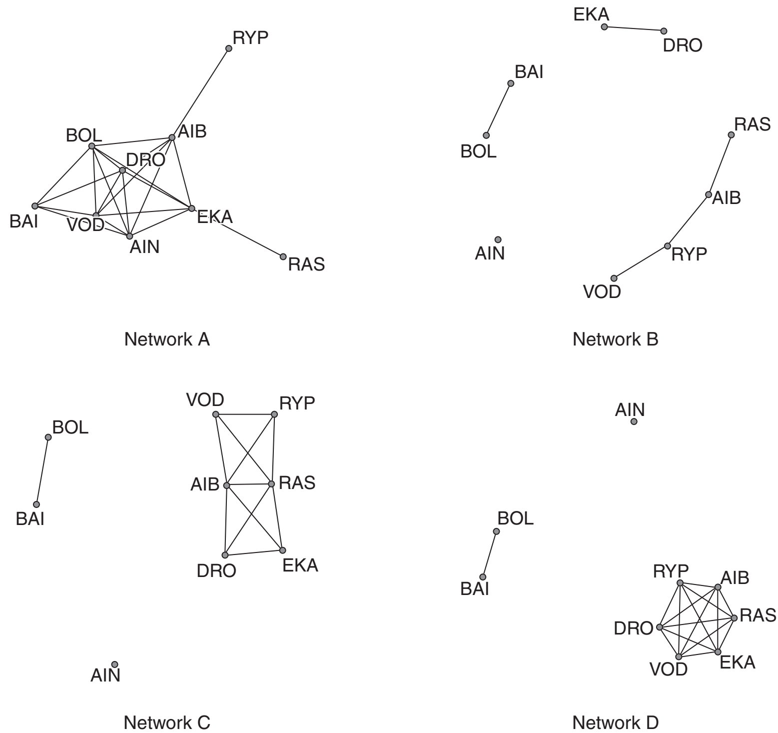


**Fig. 12.3.** Network of relationships for the Okhotsk cultural period. A: Observed ceramic exchange network derived from source provenance analysis; B: Local production exchange network model; C: Reciprocal exchange network model; D: Central place network model.

within an island group are linked to all other sites to mirror central place production or redistribution system.

Working from the premise that the formation and maintenance of social networks is an adaptive mechanism for mitigating environmental risk and uncertainty in the Kuril Islands, we can provide several basic expectations for regional network structures. During the Epi-Jomon period, migrating groups from Hokkaido colonized the southern and central Kuril Islands, and the majority of the Epi-Jomon sites that contribute to the artefact assemblage analysed in this study are located in the southern islands. The southern Kurils are larger, located close to Hokkaido, and can be characterized as having lower environmental risk due to higher levels of environmental and ecological diversity, resource predictability, and primary production. Given that participating in locally oriented regional networks is less important in the southern islands, it is expected that Epi-Jomon ceramic-based exchange networks will be less integrated (less dense), with fewer ties between southern Kuril

archaeological sites consistent with a local production model. Conversely, Okhotsk-culture sites are concentrated in the central and northern parts of the island chain. The central Kurils are smaller, steeper, located further away from mainland areas, and have lower levels of environmental and ecological diversity, and subsistence resource predictability and primary production. In this setting, maintaining a dense network of locally oriented relationships would be considered an optimal strategy for dealing with environmental variability. Okhotsk sites are expected to show a high level of connectivity in a dense, interconnected network structure representative of a reciprocity model. Several different methods of SNA analysis and testing will be used to evaluate these exchange model expectations of the networks derived from ceramic artefact data as outlined below.

### 12.5.2 Reconstruction of Kuril Island Exchange Networks Using Ceramic Artefacts

Overall, fifty-six ceramic artefact samples were submitted for ICP-MS (inductively-coupled plasma mass-spectometry) elemental analysis at the Institute of the Earth's Crust, Russian Academy of Sciences-Irkutsk under the supervision of Dr. Sergei Rasskazov. The analysed assemblage included thirty-one Epi-Jomon and twenty-five Okhotsk ceramic artefacts. Cultural affiliation of the ceramic artefacts was determined through the identification of key diagnostic stylistic and morphological features, and radiocarbon dates obtained from associated charcoal samples recovered in the same excavation unit and stratigraphic contexts. Ceramic sherds were selected from seventeen sites on eleven islands to provide the broadest spatial coverage across the island chain.

Once the elemental concentrations were obtained through ICP-MS analysis, principal component analysis (PCA) was used to identify the major elements of interest for Epi-Jomon and Okhotsk classified ceramics. In order to integrate the ICP-MS data with previously performed pXRF analyses (Gjesfjeld 2010), elements evaluated by PCA were limited to those identified by both methods. The most significant elements for each ceramic set were identified and hierarchical clustering was used to identify preliminary source macro-group clusters. In order to derive a network structure from the ceramic source data, each site within the same geochemical source group was assumed to have an exchange relationship. A binary socio-matrix of the relationships between sites was then created and analysed using the statnet program (Handcock et al. 2003) in the R statistical environment (R Development Core Team 2010). By simple visual inspection of the artefact-derived networks (Figs. 12.2A and 12.3A), it is evident that Okhotsk network is clearly different from the Epi-Jomon network by demonstrating a higher number of links between sites. While visual inspection of a network is useful in preliminary interpretation,

more detailed interpretations networks must rely on the statistical evaluation of the individual and structural properties of the networks.

The preliminary visual interpretation of the ceramic source data tentatively confirms our expectations for lower density, locally isolated networks during the Epi-Jomon period, and higher density, locally connected networks during the Okhotsk period. This confirmation is based upon the differences in the diversity of sites represented in each of the cluster diagrams. For example, in the seven geochemical source groups identified in the Epi-Jomon cluster diagram, each source group can be tentatively associated with one particular site (using a 50 per cent majority rule). In contrast, only one of five source groups in the Okhtosk ceramic network has a site that can be considered as the majority.

### 12.5.3 Evaluation of Network Structures

In order to evaluate our preliminary expectations we will utilize individual and structural approaches of social network analysis. As discussed above, individualistic approaches focus on node-level indices (NLIs) and help to provide interpretations concerning the role and position of nodes in the network while structural approaches focus on graph-level indices (GLIs) to help identify broad trends of network relationships and test archaeological hypotheses.

Developing centrality scores for Epi-Jomon and Okhotsk networks based upon the ceramic artefact distribution in geochemical source groups can help explore nodes or sites that may be of most prominence in the network. Prominent nodes have been interpreted as key locations to the flow of information or goods in the network (Hunt 1991; Mizoguchi 2009). In evaluating the centrality scores of the Epi-Jomon and Okhotsk networks, clear differences between the networks can be identified (see Table 12.1). For instance, the Epi-Jomon ceramic source network demonstrates low degree-centrality among many of the archaeological sites with only the site of Kompaniskii showing slightly higher degree and betweenness centrality. In contrast, the Okhotsk network shows higher overall levels of degree centrality with six archaeological sites considered equally prominent in the network. While these centrality measures are informative, producing meaningful interpretations of the networks can be difficult as equally plausible reasons for centrality in the network could be considered. For example, are the higher centrality values for Kompaniksii due to its role as a central place market or is it a site that needs more network ties based upon the greater environmental risk of that local area?

In order to refine potential interpretations, it is necessary to examine the structural properties of networks in addition to node-level properties. In this research we emphasize the use of graph-level density, which provides a structural property that can further contextualize interpretations based upon node-level centrality measures. For instance, we can refine our preliminary

**Table 12.1.** Degree centrality measures for Epi-Jomon and Okhotsk sites

| Epi-Jomon Sites | Degree | Betweenness | Eigenvector | Okhotsk Sites | Degree | Bewtweenness | Eigenvector |
|---|---|---|---|---|---|---|---|
| Ainu Creek | 0 | 0 | 0 | Ainu Bay | 6 | 7 | 0.366 |
| Berezovka | 2 | 2 | 0.2927 | Ainu Creek | 6 | 1 | 0.4 |
| Chirpoi | 2 | 5 | 0.439 | Baikova | 4 | 0 | 0.288 |
| Kompaniskii | 4 | 13 | 0.488 | Bolshoy | 6 | 1 | 0.4 |
| Kubyushevskaya | 2 | 5 | 0.439 | Drobnye | 6 | 1 | 0.4 |
| Olya | 1 | 0 | 0.293 | Ekarma | 6 | 7 | 0.366 |
| Rasshua | 2 | 3 | 0.243 | Rasshua | 1 | 0 | 0.066 |
| Rikorda | 1 | 0 | 0.293 | Ryponkicha | 2 | 0 | 0.066 |
| Sernovodskoe | 2 | 3 | 0.244 | Vodopodnaya | 12 | 1 | 0.4 |

**Table 12.2.** Network density scores for the observed network derived from Kuril ceramic artefact provenance analysis and the hypothesized exchange models

| Network | Density | Network | Density |
|---|---|---|---|
| Epi-Jomon Ceramic artefact provenance network | 0.2222 | Okhotsk Ceramic artefact provenance network | 0.5833 |
| Epi-Jomon Local exchange model | 0.0833 | Okhotsk Local exchange model | 0.1389 |
| Epi-Jomon Reciprocity exchange model | 0.2222 | Okhotsk Reciprocity model | 0.3333 |
| Epi-Jomon Central place model | 0.6111 | Okhotsk Central place model | 0.4444 |

interpretations of the Epi-Jomon network by examining the low graph density values (Table 12.2). The low structural density of the Epi-Jomon network suggests that Kompaniskii does not represent a central exchange location, as potentially interpreted from the centrality score, but rather a loosely connected reciprocal exchange network with one site maintaining a slightly greater number of ties. In other words, the Kompaniksii site is the most well-connected site within a very low connected network. On the other hand, the Okhotsk network demonstrates contrary properties to the Epi-Jomon network with a graph density value much higher and closer to the graph density values of the reciprocal or central place model networks. The higher overall density helps to reinforce preliminary interpretations of a more interconnected network, potentially a reciprocal or central place model, during the Okhotsk occupation of the central islands.

Producing interpretations based upon the descriptive statistics of node and graph level measures has been one of the most common uses of social network analysis in multiple fields of study. While these descriptive statistics are useful for exploratory analyses, the creation of robust interpretations requires a hypothesis-testing framework. Without a hypothesis-testing framework, evaluation of the network similarities and differences can be largely influenced by several forms of bias, including research priorities, excavation strategies, and sample size. For instance, the Epi-Jomon and Okhotsk networks are identified as having differences in centrality and density values, but it is difficult to evaluate statistically whether the difference between the networks is meaningful given that the differences exist in graph size and the ceramic samples used to construct the network graphs.

The implementation of a hypothesis-testing framework to evaluate interpretations of network data requires two analytical steps. The first step is to identify whether ties in the network can be considered as representative of social or exchange relationships rather than a random configuration of network ties. In order to evaluate the non-randomness of the networks the conditional uniform graph (CUG) test method is implemented. Results of the CUG test performed on the Epi-Jomon and Okhotsk ceramic source

**Table 12.3.** CUG test results

| Network | Pr(X>Obs) | Pr(X<Obs) |
|---|---|---|
| Epi-Jomon (Graph Density/Size) | 0.999 | 0.001 |
| Okhotsk (Graph Density/Size) | 0.216 | 0.868 |

networks reveal the definitive non-randomness of the Epi-Jomon network and the tentative non-randomness of the Okhotsk network (see Table 12.3 and Figs. 12.4 and 12.5). These results suggest that for the Epi-Jomon network we can interpret the distribution of ceramic artefacts in geochemical source groups as likely reflective of the mechanisms of ceramic production and exchange. For the Okhotsk network, this interpretation is not as definitive but the results generally tend towards linking the distribution of ceramic artefacts within geochemical source groups with ceramic production and exchange.

Once networks are demonstrated to tend towards non-randomness in their tie distribution, we can begin the process of evaluating multiple hypotheses/

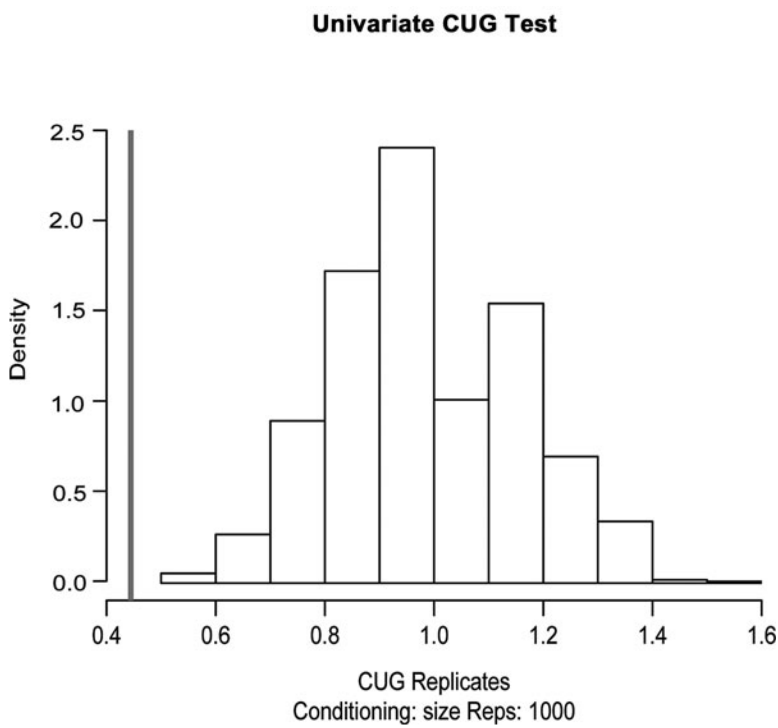


**Fig. 12.4.** Epi-Jomon CUG test results.

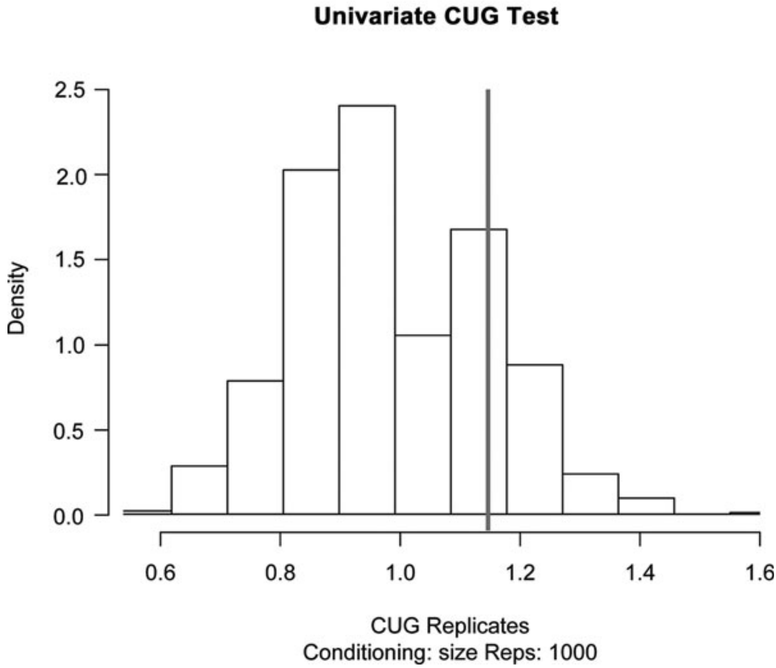


**Fig. 12.5.** Okhotsk CUG test results.

interpretations of ceramic exchange using network regression. Here, the three models of ceramic exchange (local production, reciprocal, and central place) are regressed against the networks derived from ceramic source groups affiliated with the Epi-Jomon and Okhotsk occupations. Unfortunately, the results of the network regression tests (Table 12.4) are inconclusive in terms of associating the ceramic source networks with our generalized exchange network models since the probability values do not suggest any significant departure from the null hypothesis of no association. In other words, our network models of exchange (local, reciprocal, and central place) do not explain a statistically significant portion of our network based upon the distribution of ceramic artefacts in geochemical source groups. The inability to draw significance between the exchange models

**Table 12.4.** Network regression test results

| Network/Model | Pr(X> = b) | Pr(X< = b) |
|---|---|---|
| Epi-Jomon Ceramic artefact network/Local exchange model | 0.496 | 0.504 |
| Epi-Jomon Ceramic artefact network/Reciprocity exchange model | 0.322 | 0.787 |
| Epi-Jomon Ceramic artefact network/Central place model | 0.282 | 0.742 |
| Okhotsk Ceramic artefact network/Local exchange model | 0.377 | 0.628 |
| Okhotsk Ceramic artefact network/Reciprocity exchange model | 0.609 | 0.406 |
| Okhotsk Ceramic artefact network/Central place model | 0.365 | 0.635 |

and ceramic source networks is not fully unexpected given the generic nature of our exchange models. Future work aimed at gaining explanatory significance using network regression likely needs to utilize more regionally specific models that incorporate the local and regional influences on exchange patterns.

## 12.6 DISCUSSION AND CONCLUSIONS

Archaeological research in the Kuril Islands has demonstrated that various systems of interpersonal relationships existed and were important for the procurement of raw material resources. In relatively isolated and environmentally unpredictable environments, the development and maintenance of social networks can be viewed as an adaptive strategy aimed at retaining a high level of cultural resilience in the face of change at varying scales, from short-term natural hazards to longer-term climatic shifts. The archaeological record provides the basis for evaluating ideas about the structure of Kuril Island social interactions and how they may have changed through time. Various SNA techniques and methodologies are available for not only describing and visualizing, but also statistically testing hypotheses derived from models of human exchange and interaction.

While node- and graph-level network measurements such as actor centrality and graph density are important initial steps for painting a broad overview of observed network relationships derived from artefact data, they cannot be relied on to explain the network structure, or to evaluate multiple interpretations of the behaviour represented in the network. Random graph modelling and network regression are two techniques that provide more appropriate quantitative methodologies for evaluating interpretations of network behaviour within a hypothesis-testing framework. These methods allow for the comparison of two (or more) networks in a way that has both conceptual as well as statistical significance.

In the present case study, network modelling and regression testing were used to evaluate models of ceramic production and exchange with social network structures in the Kuril Islands across two culture periods of island occupation in the archipelago. Exchange is often viewed as a direct proxy for social networking, and in some cases exchange relationships may provide a close approximation of social network structures. However, the network structures derived from the ceramic artefact record of the Kuril Islands are not well-explained by various models of ceramic production and distribution. A key conclusion drawn from this comparison is that we may not necessarily be able to rely on traditional models of exchange to explain network structure and behaviour. Additional work on exchange models emphasizing network relationships is warranted in the Kuril Islands

and future work aims to increase data resolution through the ongoing analysis of island occupation sequences. These refinements should allow for the creation of a deeper and more detailed account of the role social networks played in the ability of people to survive and thrive in the Kuril environment.

The associations between human behaviour and its archaeological correlates have long been a central research goal of anthropological archaeology. Social network analysis provides a unique research framework that can evaluate models of personal relationships characterized in anthropological theory with archaeological evidence of human interactions. The integrative power of SNA makes it a useful set of conceptual and statistical tools that can not only evaluate specific models of interaction but also expand our conceptions of the archaeological record.

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# 13

## Old-Boy Networks in the Indigenous Caribbean

*Angus Mol and Jimmy Mans*

### 13.1 INTRODUCTION

Past and present networks in the indigenous Caribbean, consisting of the Caribbean islands and adjoining mainland regions, provide a challenging opportunity for those who want to reconstruct them on the basis of mobile material culture. Two case-studies are employed in which the interactions of individuals and communities are modelled as networks using a Social Network Analysis (SNA) approach with data from (ethno-)archaeological research. One is based on ethnographic data from a small, indigenous village in western Suriname, while the other is based on past insular Caribbean networks, specifically from Late pre- and early historic Hispaniola (modern-day Haiti and the Dominican Republic). In the former we discuss the intra-site network problems and opportunities faced by a contemporary indigenous leader and his community in Suriname, on the basis of the observed and accumulated exchange of objects within the boundaries of a single village. Subsequently, the case study building on insular Caribbean historical records continues with a discussion of various pre-colonial actors and their network roles, incorporating the influence of the role of various political specialists.

SNA approaches are an established research theme in the social sciences at large and are on the rise in archaeology (Borgatti et al. 2009; Knappett et al. 2008; Sindbæk 2007; Terrell 2008, 2010). In particular, this chapter will explore how SNA can contribute to our understanding of indigenous Caribbean sociopolitical systems. Based on the idea that network connections entail network power, network centrality analyses are especially relevant to understand the position and number of connections of certain nodes in the network in relation to other nodes (Knoke 1994). In this chapter we will

focus specifically on so-called degree and betweenness centralities of socio-political actors.[1]

We will employ compatible theoretical and analytical SNA approaches—i.e. network as a heuristic and as a methodological tool—in both case studies. So, although the datasets have a different scope and quality, they can be connected from a network perspective. Furthermore, in contrasting these case studies, differences and similarities in indigenous Caribbean networks are highlighted, which in turn aids our understanding of the strategies actors could employ to gain network power.

## 13.2 A CONTEMPORARY NETWORK CASE STUDY FROM THE MAINLAND CARIBBEAN (GUIANAS)

The network analyses from an ethnographic perspective will provide us with an insight into the different roles of social actors in a single village, their connection with each other, and with the wider regional network which was created through the foundation of this village. In network terms this can be considered a 'place-centred' network, meaning that we focus on interactions at the intra-site level of a small, Trio-Okomoyana village of Amotopo in Suriname. Amotopo was founded only a decade ago (see Fig. 13.1).[2] The inhabitants of this small and young village originally came from the mother village of Kwamalasamutu. With an estimated 600 inhabitants Kwamalasamutu is the largest Trio village today (Carlin and van Goethem 2009: 17). Its leader, Asongo, is the leader of all Trio (Paramount chief or *Granman*). The village of Kwamalasamutu is situated in the south of Suriname, near the border with Brazil's Pará state. Around the turn of the millennium, *Granman* Asongo decided that several families should leave the village due to political matters

[1] A degree centrality analysis is the most basic analysis of network power and is based on the total amount of edges connecting to a certain node, $C_D$ (v), which can then be analysed in relation to the degree centrality of other nodes in the network (Ulrike and Brandes 2009: 20). Because the network data presented here is based on edges that are directed, we will be using two other versions of degree. Indegree centrality is calculated by adding up only the incoming edges of a certain node, $C_{iD}(v) = d^{-}(v)$, while outdegree only counts those connections that leave the node, $C_{oD}(v)=d^{+}(v)$.We will also discuss the betweenness centrality of nodes, $Bi=\Sigma\Sigma_k<jgki/jk.j$ and $k\neq i\neq j$. This centrality analysis is an often used centrality analysis in SNA since its introduction by Freeman (1977). Because it is aimed at finding the shortest paths between nodes in the network, betweenness centrality allows one to pinpoint the amount of influence a node has over 'traffic' going through the network. If a node has a relative high betweenness centrality it means that it is on many of the shortest paths between nodes relative to the other nodes in the network (Ulrike and Brandes 2005: 29–31).

[2] Trio is an amalgamated group composed of several ethnic (sub)groups, of which the Okomoyana (the Wasp people) is one. They speak the Trio language as their first language (Carlin 2004; Carlin and van Goethem 2009: 17).

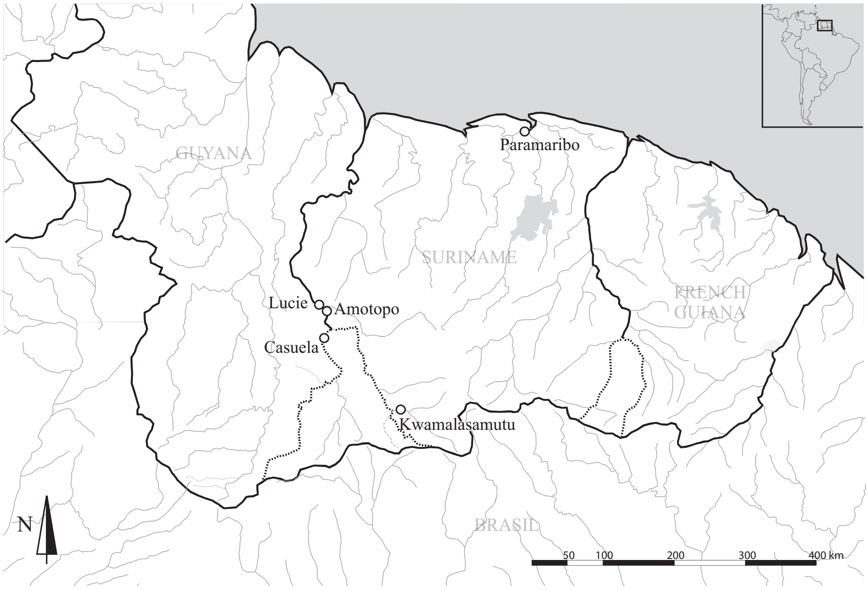


**Fig. 13.1.** Suriname and the Trio villages mentioned in this case study.

and exhaustion of the village's environmental resources. A few left in a northwestern direction, where they founded new villages on the banks of the Corentyne river. This is how two Okomoyana (a Trio subgroup) stepbrothers founded their own villages, Lucie and Amotopo, in ancestral Okomoyana land approximately 170km to the northwest of Kwamalasamutu (Carlin and van Goethem 2009: 17; Mans 2011: 242–4).

Since we attempt to link conceptually this ethnographic case study with the following archaeological case study, there is a focus on material culture as an indicator of network connections. Broadly speaking, two motivations for the exchange of goods can be found in Guiana ethnographies. One results from a lack of a skill or resource in a certain region. Ethnographic examples are, for instance, the exchange of the Akawaio who receive pots from the Patamona, the trade of spirit stones from the Kamarakoto, and the Waiwai exchanges of manioc graters and hunting dogs for manufactured goods with the Trio (Butt-Colson 1973: 10, 16–17: Howard 2001: 226, 229). The second motivation for exchange does not depend on the lack of skill or raw material in a certain region, but instead on the maintenance of social ties.[3] This means that

[3] Peter Rivière argued that Amazonian 'wealth' is not necessarily vested in the material object, but this 'wealth' should instead be found in the control of human labour, which is attracted by men in the form of women and son-in-laws (Riviere 1984: 87–94). Nowadays the notion of social wealth is also to be defined for other aspects of Amerindian life in the Guianas (e.g. the notion of territoriality; see Brightman 2008: 23–4). The material object itself seems no longer to bear any

although the necessary resources and skills are present in or near their own village, the raw materials or completed objects are acquired from another village for the benefit of maintaining social relations (Chagnon 1968: 100–1, cf. Thomas 1972: 23; Rivière 1984: 82). For instance, Chagnon describes how some Yanomamö families claimed to no longer possess the skill for pottery making and, besides, that clay in the vicinity was not suitable. However, when their allies, from whom they usually received the pots, suddenly became enemies, they instantly 'rediscovered' the skill of pottery manufacture from local clay. In short, the motivation for exchange is not alone born out of desire for material resources, but instead also out of the desire to engage in local and regional networks.

Most studies from the Caribbean mainland imply that the actors involved in exchanges of both necessary material resources and the production of social wealth are men. This assertion mainly rests on an inside-outside dichotomy in Amerindian Amazonia that dictates a gendered labour division. Roughly speaking, men deal with everything that comes from the outside, and women cultivate those (beings and matter) that belong inside the village (cf. Boven 2006: 27; Grotti 2007: 93–4). This means that in most cases men are the ones bringing objects to the village, since they are 'outside', as they frequently travel.[4] However, not all men are considered good traders; this depends on their ability to deal with outsiders. In Amerindian-Guiana being a good trader is typically a trait ascribed to a leader (Thomas 1972: 31; Rivière 1984: 73; Brightman 2007: 20–1, 31–2). When a leader is chosen he is expected to lead in negotiations with outsiders, to be a spokesperson. As a result, leaders are considered the persons responsible for the physical act of trade (Brightman 2008: 26).

In the following these generalities are confronted with intra-site-level analyses of the village of Amotopo, in an attempt to go beyond the inter-village 'old-boy network' façade of male leaders as traders. In addition, we demonstrate how the two different spheres, one resulting from the desire for material objects and the other out of a desire for social wealth, are interlocked.

### 13.2.1 Amotopoan Network of Observed Exchange

The first network is based on observed artefact exchanges that took place between Amotopoans and their exchange partners outside the village during

value for social anthropologists. Their theories should be considered a challenge for archaeologists in this region.

[4] As Rivière implicitly states: 'There are three reasons why the Trio travel away from their agglomeration [ . . . ] curiosity, search for a wife, and trade' (Rivière 1969: 51; see also Thomas 1972: 20–3).

three months in the rainy season of 2008. The nodes in the network are actors both inside and outside of the village of Amotopo. The transaction of objects signifies relations between these actors and is visualized by the edges in the network.[5] This network of exchange represents a timeslice of ongoing, delayed reciprocal actions, therefore, in most instances only one 'half' of the exchange process could be recorded. When an exchange from one person to another contained several items, these were all counted individually. In the case of exchanged animals, all were counted separately, even if it concerned certain body parts of an animal (in line of MNI). For some botanical gifts a further differentiation was made.[6] In this way a total of 133 gifts could be differentiated (for a division of types of objects see Fig. 13.2).

The 133 object edges connected thirty-threee social nodes, of whom eight were inhabitants of the village of Amotopo. In the figures in this chapter, four of these inhabitants were selected for further analyses testing their centrality in the network (see note 1 for a further discussion of the analyses). Together they are the two most central marital pairs that formally lead the village. The first marital pair is formed by AMO-01 who is the *Kapitein* (the officially

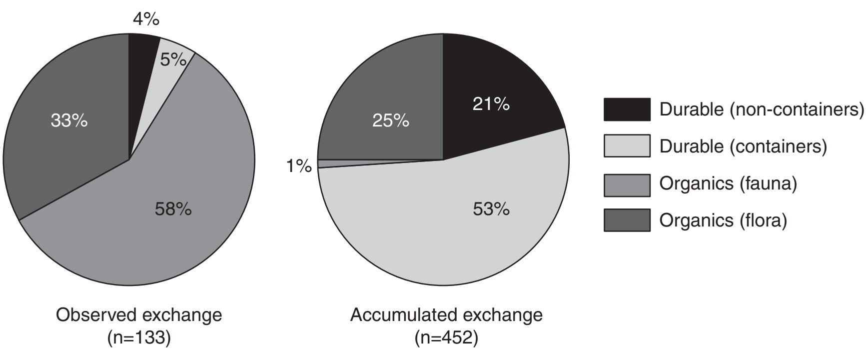


**Fig. 13.2.** The separate categories of objects of both observed and accumulated Amotopoan exchange.

[5] The edges which represent objects are ascribed a value from 1 to 4: the value '1' was ascribed to transactions consisting of durable non-container items ranging from machetes, axes, to nylon bird nets; the value '2' was ascribed to all durable container items including all metal pans and plastic bottles and bags; the value '3' was given to gifts of animals ranging from living pets to dried, salted, or smoked animal parts; and finally the value '4' which was ascribed to all organic (botanical) gifts including items such as cassava products, arrow reeds and beads made from seeds.

[6] In only a few instances, a large organic (botanical) individual gift was divided into smaller gift units to make its value apparent in the network. For instance, the incidental case of a large gift of thirty-five arrow reeds was documented in the network as seven separate gifts of value '4', since the smallest exchange of reed observed was five arrow reeds.

authorized leader, 'Captain' in English) of the village, and AMO-02 who is his wife. The second pair is formed by the eldest son of the first pair, AMO-03, and his wife AMO-04, who is a *basja* (officially authorized assistant of the village leader). In describing the exchange of items, it soon became clear that the exchange of animals forms a crucial part of the observed exchanges (see Fig. 13.2). All of the animals in the network were caught by the Amotopoan men and were handed to the women for preparation. Fish or game that was meant to be given away, may be prepared by either men or women. The *Kapitein* of the village in this case, however, is not so much occupied with hunting and fishing, but is mostly concerned with collecting, crafting, teaching, preaching, and leading the village.

Likewise he is less active in exchanges, which is reflected in his low centrality in respect to all centrality analyses (see Fig. 13.3). AMO-02 appears to play a far more important role. With her, and to a lesser extent also with her daughter-in-law (AMO-04), resides the network knowledge of several spheres of exchange, especially regarding the observed food exchange. She is the one who knows who ought to get what (see also Thomas 1972: 23–4). In this case, trade is not just a man's affair but is in part mediated by women: the women have an influence on the decision process of the trade 'inside' the village; the men subsequently perform the actual, physical trade 'outside' the village.

AMO-03 has a high outdegree centrality (see Fig. 13.3). He is important because he provides the bulk of all the fish and game to his fellow Amotopoans and to those outside of the village. He is also relatively well connected along short routes to the other nodes in the network and he has access to several exclusive nodes in the network. This is reflected in his high level of betweenness

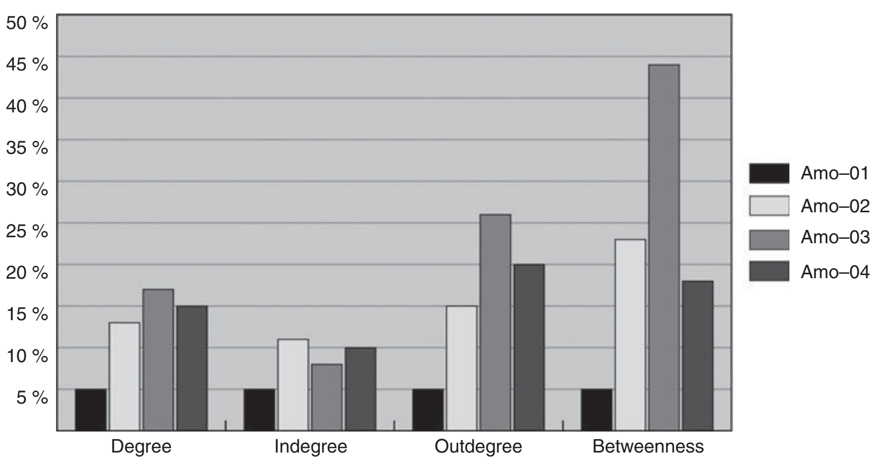


**Fig. 13.3.** The different calculations reflecting the relative position of four of the social nodes in the network analysis of the observed exchange.

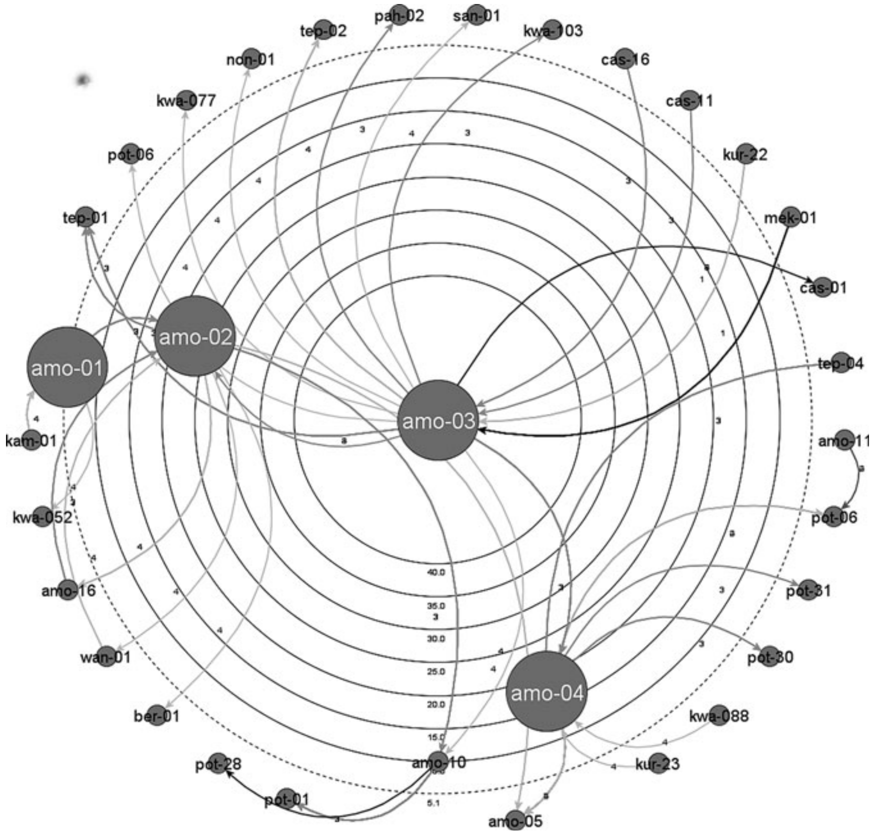


**Fig. 13.4.** The observed exchange network of the Amotopoans in the rainy season of 2008, showing the relative level of betweenness.

centrality. This puts him in a powerful position on network routes between Amotopoans and non-Amotopoans as a network 'gatekeeper' and with his many connection he is a vital part of the Amotopoan network (see Fig. 13.4).

AMO-03 not only functions as a gatekeeper for the relatives within his own village, but also for several villages that lie to the south and the north of Amotopo. For instance, although not incorporated in the current dataset, there is a long-standing tradition of inter-tribal exchange between the Waiwai and the Trio that plays a role in Amotopoan interactions. The eldest son (AMO-03) contributes to these interactions by receiving hunting dogs and manioc graters from the Waiwai village of Casuela and subsequently taking them to the Maroons near the coast in return for manufactured goods from Paramaribo (see also Howard 2001: 229).

Several conclusions can be drawn from these network centrality analyses. The first is that AMO-01, an important political figure, plays only a minor role

in this exchange network. Mostly his eldest son is active in exchanges with outsiders. The two wives (AMO-02 and AMO-03) have a higher indegree than their husbands (see Fig. 13.3). This is because they receive, prepare, and redistribute animals for exchange, which they receive from the eldest son. Next to this they exchange a portion of their own acquisitions and processed root crops and seeds. Remarkably, the Amotopoans gave far more than they received within the observation period. This is most probably related to the rainy season: many preferred animals grow 'fat' in this season due to the ripening of specific seeds. Furthermore, as no other people hunt and fish in the area, yields are generally high. This situation is exploited to produce a surplus of food for exchange purposes. This appears to be Amotopo's chosen exchange specialization.

### 13.2.2 Amotopoan Network of Accumulated Exchange

The second network analysis has a more specific spatial intra-site context that concentrates not on the act of exchange, but instead on the accumulation of objects in houses. Amotopo, which is situated on the eastern river bank of the Corentyne river, covers an area of 0.81 hectares and contains sixteen main structures which act as habitation, kitchen, and storage units. In 2008, nine of the sixteen large structures were in use. The others were usually maintained by villagers who were away during the fieldwork or no longer lived in Amotopo. An object inventory was made of six of these structures (see Fig. 13.5).[7] These included two habitation structures (ST-12 and ST-20), three kitchen structures (ST-10, ST-21 and ST-37), and a storage structure (ST-22). All six structures were used by the four individuals discussed in the former section. A total of 452 objects were inventoried.

To interpret these data it is necessary to understand the social situation. Although being founded by two stepbrothers and their families, one of the brothers decided early on to found another village (Lucie), which is situated 5km downstream from Amotopo. The younger stepbrother became the *Kapitein* of Amotopo. In 2008 the village of Amotopo comprised himself and his wife, together with three of their sons and their families. The inventoried structures can be divided into three groups. The first group is that of the habitation structure ST-20, kitchen structure ST-21, and storage structure ST-22. These belong to the *Kapitein* (AMO-01) and his wife (AMO-02). The second group is that of habitation structure ST-12 and kitchen structure ST-37, together belonging to the eldest son (AMO-03) and his wife (AMO-04).

[7] The other three structures were not inventoried due to the fact that they belonged to new Amotopoans with whom no bond of trust with the researcher yet existed.


**Fig. 13.5.** Amotopo and the six inventoried structures.

The remaining structure is the communal cassava kitchen structure ST-10, which is used by all.

In essence, the four central network actors from the previous analysis form the core group of Amotopo. This core group was asked, for each of the 452 objects, whether they had acquired them themselves or whether they had received them from someone else (for a division in types of objects, see Fig. 13.2). For 170 objects (38 per cent), it was either no longer known how these had ended up in the structures or they were objects which were procured or bought and brought into the village by the Amotopoans themselves. The remainder of 282 objects (62 per cent) were received by the Amotopoans either as gifts or through exchange with others, the transactions of which and with whom could still be remembered. These data were used in the present analysis. The result of this inquiry is an 'archaeological' record of over 30 years of network interactions by these four actors as reflected in their house inventories.

The absolute number of connections of nodes in this network, reflected in their degree centrality, shows that the *Kapitein*'s wife (AMO-02) has the highest centrality (Fig. 13.6). Again, the Kapitein (AMO-01) has the lowest degree of centrality in this network, excepting his outdegree centrality. AMO-03 has a much higher outdegree than AMO-01. This is probably because he acquires much of what comes into the village, before he distributes it amongst his relatives. So, the women receive their kitchen utensils and other domestic

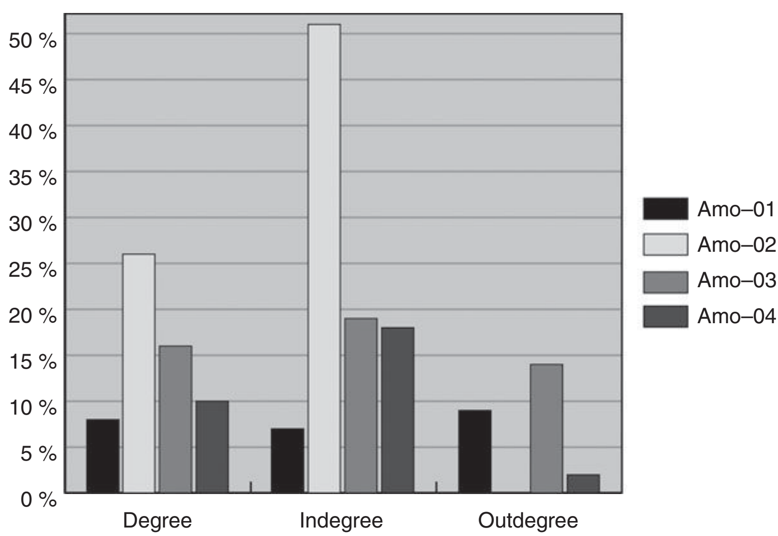


**Fig. 13.6.** The different calculations reflecting on the relative position of four of the social nodes in the analysis of the accumulated exchange.

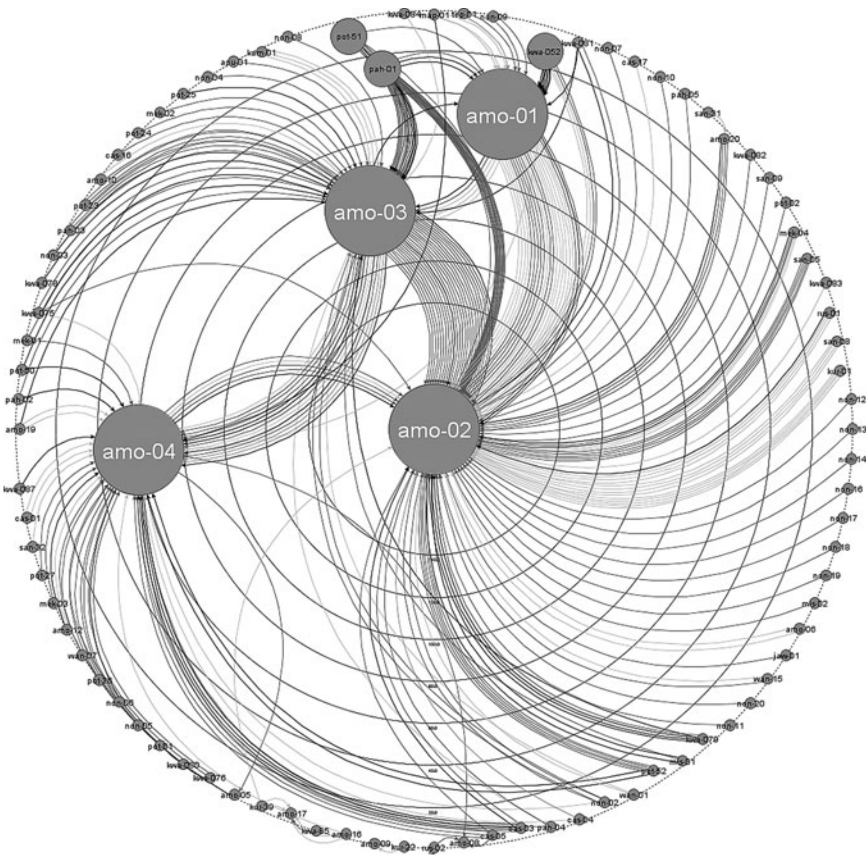


**Fig. 13.7.** The accumulated exchange network of the Amotopoans in 2008, showing the absolute level of degree.

items, most of which are durable containers, via the men.[8] That is why the centrality of the wives, whose outdegree is small but who have a very high indegree, contrasts sharply with that of their husbands. When plotting the accumulated objects in a network it becomes clear that AMO-02 is at the receiving end of most exchanges (see Fig. 13.7).[9] This corroborates the results of the network power analysis derived from the observed exchange.

[8] In the 1960s Peter Rivière also noted that women had more possessions than the men, because of the kitchen utensils (1969: 40).

[9] Exchanges occurred not only between marital pairs (versus Howard 2001: 39). Upon asking who had received what, individuals were named and not marital pairs. The marital pair is the main economic unit, but this being said, network roles, although strictly gender divided, are based on individual strategies.

The above centrality analyses of Amotopo contrast sharply with the notion of an 'old-boy network' of exchange. The village leader is neither responsible for exchanges, nor the most important network actor in the studied spheres of exchange. AMO-03 does appear to possess the necessary network qualities of one who negotiates with outsiders, as reflected in his high betweenness centrality for observed exchanges and degree centrality in the network of accumulated goods. Additionally, the fact that he has a high outdegree centrality in both networks shows that he is not amassing material wealth, but rather, building up social capital. The female actors, AMO-02 and AMO-04, have an unexpectedly high degree centrality in both networks and a relatively high betweenness centrality in the network of observed exchanges. This is indicative of a much more active role of women in local and regional networks of exchange than is recognized by previous studies.

## 13.3 A PAST NETWORK CASE STUDY FROM THE INSULAR CARIBBEAN

The insular Caribbean is a nearly continuous chain of inter-visible islands running from Trinidad in the south to the Bahamas in the north. Islands in this chain are geologically, ecologically diverse, meaning that even smaller, distant islands would have had unique resources to offer, stimulating inter-regional mobility (Cooper 2008; Hofman, Bright et al. 2007; Keegan and Diamond 1987; Keegan et al. 2008). This is reflected in an archaeological record that shows a system of associated but diverse material culture, numerous indicators for intra-regional movement of goods and raw materials, and evidence for the acquisition of social valuables from various regions of the South American mainland. It is therefore not surprising that interaction and connections are key concepts for the archaeology of the Caribbean (Mol 2011).

The fact that single archaeological sites were part of some greater system was recognized early on in the history of Caribbean archaeological research (Fewkes 1922; Lovén 1935; Rouse 1939), but the last decade especially has seen an explosion of scholarly articles and monographs on the subject (Boomert 2000; Bright 2011; Crock 2000; Curet 2005; Fitzpatrick et al. 2008; Hofman, Bright, et al. 2008; Hofman, Bright, et al. 2007; Hofman, Hoogland, et al. 2008; Keegan 2007; Keegan and Rodríguez Ramos 2004; Knippenberg 2007; Mol 2007; Oliver 2009; Rodríguez Ramos 2010a; Torres 2005). Based on the idea that the Caribbean Sea worked as a 'superconductor' for human mobility, all of these studies stress the high degree of connectedness of pre-colonial

communities (Boomert and Bright 2006; Rouse 1992; Watters 1997).[10] The complications of creating and maintaining social networks in this archipelagic setting should not be underplayed, however. The only available means of transport across stretches of open water were man-powered dug-out canoes (Bérard et al. 2011). Such sea passages were risky due to currents and rapidly changing weather conditions (Callaghan 2001). Moreover, the islands of the Greater and Lesser Antilles were linguistically, culturally, and sociopolitically diverse (Boomert 2000; Bright 2011; Granberry and Vescelius 2004; Rodríguez Ramos 2010a; Rouse 1992; Torres 2005; Wilson 1990). This would have added potential social, cultural, political, and communicative difficulties to an already challenging logistical situation.

Nonetheless, the general view from studies on pre-colonial mobility and exchange is that during the Early and Late Ceramic Age (250 BC–AD 1492), the pre-colonial Caribbean consisted of several interaction spheres that were, in a sense, autonomous but interconnected (Allaire 1990; Boomert 2000; Caldwell 1964; Mol 2011). The acquisition and exchange of raw materials and finished goods clusters massively at the local level (e.g. Knippenberg 2007; Hofman et al. 2007). However, the fact that objects were at times moved over lengthy (>150km), sometimes vast (>1000km), distances has been equally well attested (Boomert 2000; Hofman, Bright et al. 2007; Rodríguez Ramos 2010b). This means that, from a network view, the entire Caribbean forms a massive network throughout its pre-colonial history. This network would have been laid out as clusters of nodes that were well connected at the local and regional level, but with connections to more geographically distant nodes, either by direct ties or in a stepping-stone fashion through other nodes.[11]

Naturally, the massive network that is evidenced by the archaeological record cannot be portrayed adequately using network analyses because of the disparate and fragmentary nature of the available datasets. Nonetheless, using SNA some results have been obtained through an analysis of sub-networks of the larger network by delineating geographical areas and material categories (Cody 1990; Hofman et al. 2011). In addition, SNA models have been used to visualize hypothetical networks of Early Ceramic migrants and SNA theory has been used to better understand their possible network strategies (Hardy 2008). For the current case study an SNA approach will be employed to expose sociopolitical network strategies in the latter part of the Late Ceramic Age and proto-contact Hispaniola (AD 1000–1492).

[10] Nonetheless, it is clear that islands are on one level bounded entities (Fitzpatrick et al. 2007), which is intuitively perceived as a useful characteristic for SNA by many, which would explain the over-representation of island and other maritime settings in archaeological network literature (e.g. Cody 1990; Knappett et al. 2008; Terrel 2010; Sindbaek 2008).

[11] In the analysis of modern social networks, such a 'Small World' network—i.e. a large network in which all the actors still have a relatively high closeness to all other actors—is quite unremarkable, but that is, of course, due to modern media of interaction.

### 13.3.1 Network Roles and Strategies in Proto-Contact Hispaniola

In a now-outmoded view the Mona Passage between western Puerto Rico and eastern Hispaniola is perceived as a boundary area at which the original a-ceramic Archaic Age population of the Antilles managed to keep the ceramic using, colonizing Saladoid 'culture' at bay for several centuries (Rouse 1992). However, recent studies on ceramics and site patterns suggest that in Early Ceramic times the Mona Passage was already a region in which networks from the eastern and western Antilles connected (Curet 2005; Hofman, Ulloa Hung, et al. 2007; Rodríguez Ramos et al. 2008; Ulloa Hung and Valcárcel Rojas 2002). By the Late Ceramic Age Hispaniola had become the heartland of what is usually called the 'Classic Taíno' culture (Rouse 1992; Wilson 2007). This is a misnomer, since no actual 'Taíno' culture or ethnicity ever existed, rather it was used by archaeologists as shorthand for shared trends in material cultural expressions of this area. Both western Puerto Rico and eastern Hispaniola had enormous cultural—and it is suggested also sociopolitical (Crock 2000; Hoogland and Hofman 1999; Oliver 2009)—influence on the surrounding island regions (Atkinson 2006; Hofman, Bright et al. 2008; Valcárcel Rojas 2002). This is evident from various Late Ceramic Age artefacts that are distributed over a large area of which the archetypical form and style likely developed in this region, such as (variants of) the Chicoid ceramic series (Rouse 1992; Veloz Maggiolo 1972), earthen bank- or stone-lined ball courts (Alegría 1983), stone belts, elbow stones, (zoo-)anthropomorphic three-pointed stones (Walker 1993), *guaíza* shell faces (Mol 2007), (zoo-)anthropomorphic pestles, and high-backed *duho* seats (Ostapkowicz 1998).

Thus far Hispaniola and Puerto Rico are also the only islands for which the existence of *cacicazgos*, multi-tiered, regional polities headed by a chief or *cacique*, can be substantiated from available ethnohistorical sources (Curet 1992; Siegel 1992). It is suggested that these Hispaniolan and Puerto Rican polities were expanding their network through exchange or perhaps even actively colonizing other areas of the Antilles around AD 1300/1400 (Hofman and Hoogland 1994; Rouse 1992; Oliver 2009). Based on information from historic records of the contact period the estimates on the number and size of the existing cacicazgos at the end of the 15th century vary: some claim there were only five large regional chiefdoms on the island of Hispaniola, others identify up to twelve smaller polities (Wilson 1990). In all accounts the *cacicazgos* on Hispaniola, today located in Haiti and the Dominican Republic, are mentioned as large and influential polities that were connected through several types of social relations; e.g. exchanges of gifts, marital partners, and even names (Oliver 2009). It is also known that the eastern Hispaniolan *cacicazgos* had relations with several Puerto Rican *cacicazgos* (Samson 2010). These network relations with Puerto Rico were probably the reason that

the *cacicazgos* in the east were among the longest enduring on Hispaniola after the initial contact with Europeans in 1492. Only after the 'Wars of Higuey' of 1504 did the Spanish manage to break indigenous power in this region and bring the area under their control (Churampi Ramírez 2007).

Material indications of the network relations between these polities, such as the provenance of ceramic clay, can be used to connect nodes and reconstruct parts of past networks and, if the network is extensive enough, can shed light on network strategies (e.g. Conrad et al. 2008; Van As et al. 2008). However, if the network is too fragmentary, information on social institutions and strategies can be accessed via other routes and explored from an SNA perspective. In Caribbean archaeology ethnohistorical documents have played an important role in the reconstruction of pre-colonial institutions and social practices since the beginning of the discipline (Fewkes 1922; Lovén 1935). The majority of the studies done on these early sources of information on the Greater Antillean indigenous sociopolitical systems have put forth, and reinforced, the idea that the position of *cacique* was the only institute of political importance, although this view has also received some considerable critique during the last years (Curet 2003; Torres 2010).

The traditional idea is that regional cacicazgos, such as in Higuey, were headed by a paramount *cacique*, who had influence over a number of less powerful *caciques*.[12] According to some sources this class of elites is called the *nitaínos*, 'the good ones'. The class of the *naborías*—literally 'the rest'—is considered to be the commoners' class (Keegan 1997; Moscoso 1977). Some have even suggested that this pyramidal power structure was already so firmly in place by the beginning of the contact period that the *caciques* were even perceived as semi-divine beings, who were treated with veneration and decorum (Keegan et al. 1998; Oliver 1997). In this view the only politically relevant network interactions supposedly take place in hierarchical 'old-boy networks' between a few paramount *caciques* and between paramount *caciques* and their subordinate *caciques*, who in turn interact with their communities (cf. Earle 1997).

The problem is that this view is largely based on now-outmoded models of sociopolitical evolution (Chapman 2003; Pauketat 2008), and localized information for this model comes mainly from ethnographic analogies with contemporary indigenous mainland societies and historical information from the first thirty years of Spanish–indigenous contact. No clear archaeological evidence has ever been presented that would prove the supremacy of the *cacique* in this system. It seems that the 'evolutionary' reasoning behind the

[12] Note that '*cacique*' was most probably the title for the head of an extended family (Oliver, personal communication 2007). Even nowadays the term *cacique* is used in the Dominican Republic and is used for minor bosses who behave in a despotic way.

creation and consolidation of a proto-historic, all-powerful divine *cacique* is rather teleological and does not make full use of available datasets.

Actually, historical records show that there was a variety of important network actors in pre- and early colonial Greater Antillean political networks.[13] This means that, rather than accepting the supremacy of the cacical office, alternative nodes in the political network should be further investigated. Modelling the sociopolitical network and focusing on network strategies provide a means to do so. Several types of actors and their relations in the Late Ceramic Age sociopolitical network can be identified that would have been relevant from an *emic* perspective: spirits, *behiques* or ritual specialists, caciques, cacical communities, cacical heirs, and the wives of the caciques or *cacicas*.

It is important to understand the animistic social universe in which indigenous contracts and conflicts were created and mediated (Roe 1998; Siegel 1998). In a world in which all living and non-living things could potentially possess *zemi* or 'life force' (Oliver 2009), network relations did not only exist between human beings, but could also be extended to the world of the spirits (compare Santos-Granero 2007). These spirits were capable of manifesting themselves in aspects of the natural world or materializing in human-made objects, giving specific spirit actors an actual physical presence in the world such as a certain rock or a statuette. The invaluable information on the world view of the indigenous people of Hispaniola from the 1495–1497 report by Fray Ramon Pané (1999 [1571]), for example, shows that trees, rocks, and material culture objects could 'make their wishes known' and thereby enter into contracts with human beings. If these contracts were not honoured by their human counterparts these materialized spirit beings could retaliate by inflicting diseases on them or by simply leaving the community. A famous example is that of the dog-like spirit *Opiyelguobirán*, whose idol was wont to leave its house at night after which it had to be retrieved from the forest in the morning. At a certain point it was tied down to stop it from leaving, but it managed to escape nonetheless and disappeared into a lagoon (Pané 1999 [1571]: 28–9).

*Behiques* were shaman-like specialists who were able to communicate with beings that had 'zemi' like *Opiyelguobirán* and others. They did this by entering a state of trance, for example during rituals in which they purged themselves and inhaled the powdered seeds of the *Anadenanthera peregrina* mixed with chalk through the nose. Through this mediation with the spirits the *behique* was also able to cure or perhaps even inflict illnesses (Roe 1998).

[13] It is undeniably true that male political leaders seem to be the most prominent in the historic descriptions. However, we should not discount the fact that the historical sources are *de facto* male focused and that the colonizers used the structure of the cacical office as the basis for the later *encomienda*-system, which closely mimicked similar Iberian, male-dominated, feudal institutions.

The *behique* seems also to have been important as a spiritual advisor to the *cacique* and local communities, for example as a medium through which normal people could interact with dead relatives (Pané 1999 [1571]: 23–24).

Different members of the *cacique*'s community also were responsible for the creation and maintenance of specific network relations (Moscoso 1977). For instance, it is a recurrent theme in interactions between groups of Spaniards and indigenous people that before the leader of the Spanish group meets the *cacique* they first interact with another, authoritative member of the *cacique*'s community, who perhaps determines the dispositions of the strangers (e.g. Navarete 1922, 17 December: 107). *Caciques*, forming the third group of actors, however, were the acting parties in large ceremonial exchanges, often taking place in the village. An example of such an occasion is the feast held on 25 December 1492, by the *cacique* Guacanagarí in honour of Columbus and his men. Here Guacanagarí presented Columbus with several symbolically laden objects (Navarete 1922, 26 December: 129). However in smaller, non-ceremonial exchanges outside the village, it seems that gifts were sent by proxy, with a member of the *caciques*' community. A shipping list from the second voyage of Columbus catalogues a string of exchanges between Columbus and Guacanagarí, taking place in the newly founded colony of Isabela (Alegría 1980). The author of the list mentions several times that Guacanagarí sent Columbus several items. It is notable that at least two of them are brought by one of Guacanagarí's nephews, just like a similar gift before was sent by one of his nephews (Navarete 1922: 133, 229). This particular network strategy of the *cacique*'s extended kin is especially relevant with regards to cacical succession.

It seems that, after his death, the vast majority of the *cacique*'s wealth was returned into circulation during a funerary feast in which his extended kin gave away his possessions to 'foreign' *caciques* (Oviedo y Valdes 1851: Book 5, Chapter 3, 134).[14] It is not known which member of the *cacique*'s extended kin took the lead during this feast and the debate on the rules of descent and inheritance for the cacical title has not yet been settled (Curet 2002; Curet 2006; Keegan 2006). We would have to agree with Curet (2002) that, although there probably was an established practice of succession of the *cacique* by his sister's first son, there was an amount of flexibility in the rules of succession. This left room for political manoeuvring of the various actors and factions vying for the cacical office. Having the right network skills and relations offered a decisive advantage in such a competitive environment. After the death of the old *cacique*, the new *cacique* would inherit the former's title and a set of reciprocal obligations resulting from the funerary exchanges after his death. However, the new *cacique* would not inherit material wealth that could be used as capital for existent and new network relations. For prospective

[14] See Oliver (2008: 104) and also Keegan (2007) for a discussion on the function of the 'foreign' *cacique*.

*caciques* it would therefore have been even more important to accumulate social and material capital by having a strong network of one's own.

There is some confusion over the political status of the wife of the *cacique* or *cacica*.[15] It is known that in at least one case—that of the *cacica* Anacaona—the wife of a *cacique* fulfilled his political duties after his death, but it has been claimed that this was the result of stress on the political system due to the effect of early Spanish attempts at domination (Wilson 1990: 119). Nevertheless, it does seem that there was an important network role for the *cacica*, especially since in matrilineal systems of descent it is impossible to hold on to and build a material base of wealth through the male line. This means that material wealth must be accumulated through the female line (cf. Keegan 1997). In the case of the *cacica* Anacaona it seems that she indeed had several houses filled with valuable items, such as stools, statuettes, and ornaments that were kept to be released into circulation at strategic moments (Martyr D'Anghera 1912: 124–5; Mol 2007: 86–8). Additionally, the sources are unequivocal about the fact that she was an expert at dancing and conducting *areítos* (e.g. Las Casas 1986: Book 1, Chapter 114, 138–9; Oviedo y Valdes 1851: Book 5, Chapter 1, 127). These *areítos* were ritual, communal dances, which were performed at special occasions and functioned as mnemonic devices with which history could be recorded and re-enacted. They functioned as highly prestigious intellectual capital (Las Casas 1875: Book 1, Chapter 121, p. 171). The records also show that the *cacica* and other women of her community were responsible for the redistribution of food when receiving visitors (Wilson 1990: 57). So, although the *cacica* did not have a network role that directly led to the establishment of network connections, it is likely that she and other females of the *cacique*'s community remembered details of past network interactions, exerted control over network relations through the distribution of their lineage's material wealth, and were vital for the local infrastructure behind Late Ceramic Age networks.[16]

From an in-depth look at the resulting political network model it becomes clear that the *cacique* was far from the only player of importance in Late Ceramic Age power structures (Fig. 13.8). The positions of the various actors result from the different network roles that they have: *cacicas* are important network brokers in their own right, having access to mnemonic devices in the form of corporate valuables such as areítos; prospective cacical heirs would have been active in interactions with outsiders; *behiques* were tremendously important for sustaining network relations with the spirit world. So, although they have specialized roles, depending on which sub-part of the

[15] In fact, *caciques* were likely polygamous and the *cacique*'s wives were probably even ranked (Oviedo y Valdes 1851: Book 5, Chapter 3, 134).

[16] Compare Melanesian literature about the role of women in exchange networks such as Strathern (1988) and Weiner (1992).

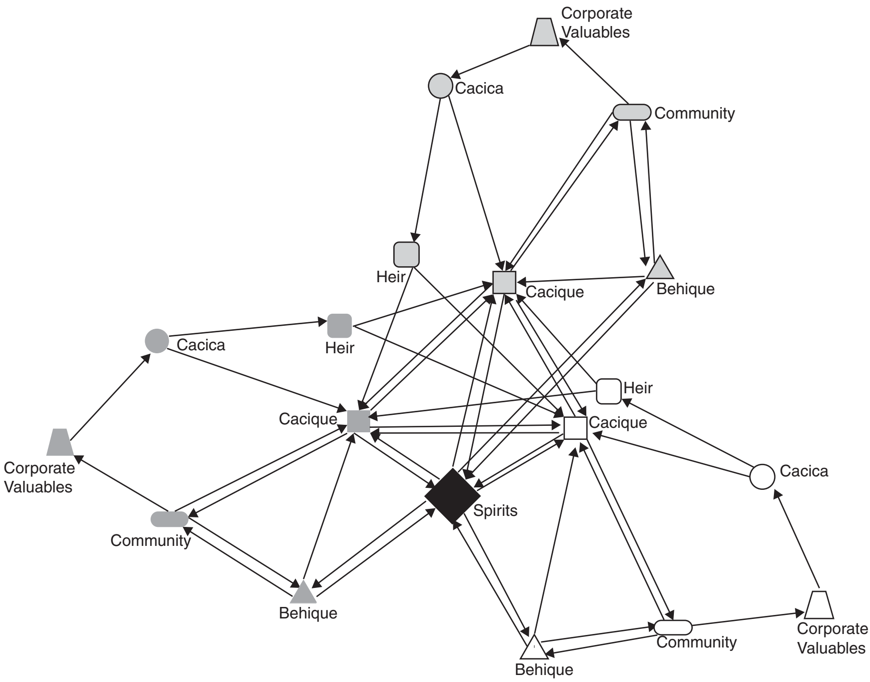


**Fig. 13.8.** A network model of the pre- and early historic indigenous political system.

network is considered, the network power of *cacicas*, *behiques*, and cacical heirs rivals that of the *cacique*. Notably, interaction with superhuman spirits takes an undisputed central role in the network. This confirms that mediation with—and manipulation of—these beings was a highly important network strategy (Oliver 1997). This is substantiated by the Late Ceramic Age archaeological record that sports a plethora of materialized spirit beings in the form of statuettes, three-pointed stones, personal adornments, petroglyphs, ceremonial paraphernalia, and other depictions made from various materials (McGinnis 1997).

It may now appear that there was no need in the network for the *cacique* himself. Yet, it has to be understood that although important network roles and strategies were also undertaken by other types of network actors, the *cacique* was a 'jack of all trades and master of none' in network terms. Although he cooperated with network specialists, he was the face of the community in elite interactions, led ceremonial communal redistributions, was a leader in war, and was able to enter into network relations with superhuman beings as well. It is exactly this versatile character that would have made *caciques* and cacical communities central players in pre- and early historic political networks.

## 13.4 CONCLUSION: CONTRASTING INDIGENOUS CARIBBEAN NETWORKS

Although they have different scopes, there are several things that can be learned from contrasting the two SNA case studies presented here. We acknowledge that sites or locations within sites make awkward network nodes for SNA, because they are not so much social entities as they are spatial units, defined by (ethno)archaeologists. Even so, site-level provenance or even stylistic analysis of material culture presents an opportunity for an SNA approach in archaeology. Depending on the quantity and quality of the available data, a rudimentary to advanced insight into the network in which actors at the site participated can be gained through SNA analysis. What the case studies show is that an intra-site perspective can be as, or even more, insightful for gauging a particular site's network relations and can reveal local fluctuations in network power for different intra-site locations. Naturally, an inter-site perspective is needed for establishing the relative network position and power of one site vis-à-vis other sites in the region. Both intra- and inter-site network perspectives can aid in establishing whether the site should be regarded as a hub in larger, regional networks.

With respect to the question of sociopolitical systems, the case studies show that there is a deep differentiation of network strategies and roles that are potentially visible on the intra-site level. Here the network abilities and strategies of different social actors determine the shape of inter-site networks and the relative centrality of their community in these networks. Similar network roles in both cases were the position of the young men who travel to make the physical act of exchange and the women who influence and determine who receives what. Finally, communal leaders might have a smaller part in the actual exchange or network strategy decision process than was previously recognized, but they ultimately build up social capital from the flux of goods that enter and leave their community. Because of missionary activities, the case of the Surinamese Trio differs with regard to the importance of ritual specialists and the spirits they interact with. Determining the precise role of Trio religious (syncretic) specialists in the networks of Amotopo and beyond is not within the scope of the present study. Nevertheless, it is clear for both the Amotopoan and Hispaniolan networks that relations visible from the study of sites are the result of a variety of different roles and strategies and not only from the accumulation of prestige or material wealth (this contrasts with, for example, Earle 1997).

In addition, all aspects of the networks under discussion—exchange of goods and accumulation of exchanged goods at Amotopo and the network strategies of different actors as can be seen through Early Contact Spanish records—show that accumulation of material wealth in at least these indigenous Caribbean

networks is subordinate to the creation and maintenance of social wealth. This takes the form of a social network of entangled, delayed reciprocal obligations with other network actors. However, it should be stressed that such an indigenous 'old boy network' does not entirely revolve around senior, male community leaders such as Hispaniolan *caciques* and the Trio *Kapitein*. Rather SNA reveals that, in actuality, alternative network actors, such as influential women and younger men, employing a variety of network strategies, can be close to or as central as the 'old boys'.

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# Part IV

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# 14

# Archaeology, networks, information processing, and beyond

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## 14.1 INTRODUCTION

The chapters in this volume give an excellent overview of the current state of affairs in SNA (Social Network Analysis) in archaeology, as well as an interesting set of case studies—both from archaeology and from other domains, such as anthropology, textual analysis, history, and geography. Reading them has greatly enriched my understanding of the current state of the domain of SNA in the historical disciplines. As discussant, however, it is my role to try to offer some suggestions about other paths that might be followed in applying SNA to our disciplines.

What strikes me more than anything in this volume is that virtually all of the contributors have used SNA as an analytical technique. They have either tried to demonstrate, by applying SNA, one or more specific hypotheses about trade, communication, or another form of interaction between people, settlements, languages, or textual elements, or they have used SNA to elicit specific information from the data about such interactions. To be fair, in linking data and hypotheses or results, the chapters have invoked various aspects of human communication, trade, and interaction. But that has been done in a 'proximate' manner; i.e. as close as possible to the actual case studies.

It seems to me that where I could be most helpful to this research domain is to try and step back and look at it from a wider social science perspective. But that implies that I have to outline, before I get into any detail about SNA, a more general take on the role of information processing in society.

## 14.2 SOCIETY IS BASED ON INFORMATION PROCESSING

Maybe one way to initiate that is to affirm from the outset that, contrary to what many seem to think in our society, the 'information society' is not an

invention of the 20th or 21st century. Indeed, each and every society, whether past or present, whether disposing of major IT capability or not, is in effect an 'information society'. The reason is very simple: of the three fundamental commodities—matter, energy, and information—that constitute the metabolism of human societies, information is the only one that is not subject to the 'conservation principle'. In other, less technical terms, information is the only one of these commodities that can be shared and can spread among people. Hence, what keeps societies together and their members involved is the fact that they share ways of processing information—including culture, institutions, language, and other communication tools, as well as knowledge and know-how about resources, the environment, techniques, and technology, and in general 'ways to behave'.

Matter and energy cannot be so shared. If I give you an object, you have it and I do not any longer. The same is true of energy. Nevertheless, energy and matter (resources) play an important role in societal dynamics, as they need to be available in sufficient quantities for a society to enable its members to function correctly. *Resources should under most circumstances be seen as a constraint.*

Another point to make in the same context is that while human beings do to some extent distinguish themselves from other animals by being able to learn, and to learn how to learn, there is in effect a more profound distinction—the fact that humans can and do *organize*. They organize themselves, matter, their resources, their environment, and everything else they come into contact with. I would argue that that capacity to generate organization in almost infinite ways depending on context, aims, and function is an even more fundamental characteristic of our species. Hence, we need to shift our thinking accordingly (Lane et al. 2009):

> The social sciences traditionally looked at the distribution of populations, power, riches, etc. in order to describe and categorize organizations ('*population thinking*'), whereas the formal approach to which we refer here focuses on looking at the underlying dynamics of organizations to understand relationships between individuals ('*organization thinking*').

## 14.3 SHIFTS IN PERSPECTIVE

The first fundamental shift in perspective that we need to embrace, as has implicitly been done by many in this volume, is that we need to look at past, present, and future from a dynamic perspective, rather than conceive of societies as more or less static structures. The dynamic is more than an aspect of the structure that creates change—the structure *is* change. *Change is all*

*there is*. In Prigogine's well-known words (1981), we need to move from a perspective that focuses on '*being*' to one that embraces '*becoming*' as the core of how we think. Societies, in this perspective, are dynamic structures.

In the words of White (2009):

> . . . the social sciences have focused on static, structural descriptions of social organization that were primarily concerned with the position of individuals in the organization, whereas the kind of formal approach we propose is, in essence, dynamical and focuses on relationships between individuals to understand the organizations that emerge and their evolution. [ . . . ]

This is a fundamental difference from the way many archaeologists have for a long time looked at human evolution—as a series of steps connecting what were essentially stable phases, in which little or nothing changed. Change is now assumed—and the absence of change needs to be explained.

It follows from this change in approach—and this is much less commonly done in archaeology, or in this volume—that we should not so much look for the origins of phenomena that we observe, but instead *look for their emergence*. Rather than take an '*ex post*' position—one in which one *looks back* to identify the origins of something—we need to take an '*ex ante*' perspective—one in which we position ourselves at a time before the occurrence of the phenomena we wish to study, and look forward in order to see how they emerge (van der Leeuw 2008). Rather than learn *from* the past how the present came about, we need to learn *for* the future—focus our learning in such a way as to gain more insight into what the future might bring.

This goes against much of our scientific tradition, which has always emphasized that in order to ground our assertions solidly we must, in as far as may be possible, prove them. Of course such proof can never be achieved by comparing the present (or the past) to the future, because that future is yet to be observed. So our science has fundamentally dealt with the relationship between present and past. In the process, we have systematically focused on reducing the experience of the many dimensions of the complex system that surrounds us to a smaller set of dimensions (in the form of a chain of cause and effect) that could satisfy our 'need to know'. Effective as that approach may have been in satisfying our curiosity about the world around us at a time when change was relatively slow, so that we could extrapolate linearly from past and present into the future, our world now changes so rapidly that such extrapolation is no longer effective in dealing with the challenges that we face. Hence the tenet of the 'complex adaptive systems' approach that I am adopting here, that we need to start looking directly at the relationship between present and future, using the whole of the modern information-processing toolkit at our disposal in order to anticipate, rather than to explain. Some of the tools that will, we expect, help us to do so are massive data mining, modelling, and scenario development.

## 14.4 SOCIETIES AS DISSIPATIVE FLOW STRUCTURES

Elsewhere, Dwight Read and I (Read and van der Leeuw 2009; in press) have looked at how that capacity to organize evolved over the 2.3 Myr period that modern humans and their precursors have lived on Earth. In other papers (van der Leeuw 1989, 1990, 1994), I have tried to outline a simple model for how one might imagine information processing working at the level of the individual, in a bootstrapping interaction between data and knowledge that incrementally increases the 'tools for thought' at the individual's disposal, as well as the data that hold information content for the person concerned.

As we are here fundamentally concerned with interaction between people in either the present or the relatively recent (Holocene) past, I will not bore you with these topics here. Instead, I will outline some aspects of an equally simplified model of how we might conceive of the interaction of groups of individuals among themselves, how they organize their environment to obtain resources, and how they manage the flows of both information and energy that effectively constitute the metabolism of a society (van der Leeuw 2007; van der Leeuw et al. 2009).

That model assumes a bootstrapping mechanism that creates organization in an interaction between solving challenges, creating knowledge, emergence of new challenges, and learning further to solve these challenges. In that process, I postulate, more and more people are brought together to solve larger and larger challenges. This process looks more or less like this:

Problem-solving structures knowledge → more knowledge increases the information-processing capacity → that in turn allows the cognition of new problems → creates new knowledge → knowledge creation involves more and more people in processing information → increases the size of the group involved and its degree of aggregation → creates more problems increases need for problem-solving →problem-solving structures more knowledge . . . etc.

But that is only the first part of the story. The human groups at the core of this mechanism also need energy and other resources, and these have to come from the society's environment. The only way to realize this is to organize the relevant parts of that environment in such a way that they yield the desired resources.[1] The larger the group of people, the more investment is needed in the environment, and that investment generally involves a wider and wider area (the 'footprint' of the society or group).

We can model the interaction between the society and its environment as a dynamic structure consisting of two flows going in opposite directions—a flow

[1] In effect, a resource is not really a resource until it has been recognized as such by a group of people, and that group has created the institutions and processes to exploit that resource, so that the resource has become an integral part of the society.

of organization ('information-processing capacity') that emanates from the society and flows towards the surrounding environment, and a flow of energy that is extracted from that environment and that flows inwards into the society. The resultant feedback loop dissipates entropy by organizing the environment and the society.[2] We will therefore speak of a 'dissipative' flow structure.

## 14.5 IMPLICATIONS FOR NETWORK THINKING

What does this have to do with the network approach proposed in this book? For one, it follows that there are two kinds of networks involved in any case study—one for organization (information processing), and one for resources (matter and energy)—and they should not be conflated or confused. In real life, these two kinds of flows have a very complicated relationship, which we may not always be able to disentangle.

To begin with, information processing creates the channels through which the energy is collected, identifying resources, organizing ways to extract them from the environment, to negotiate them, to transport them, and to distribute them to those who need them. It also generates the techniques and the institutions needed to transform them into the products the society can either consume or re-export as trade objects.

Secondly, information transmission requires a material (clay tablets, paper and ink, pottery, cloth, or other) or energetic (vibrations in the air, electromagnetic waves) substrate. As a result, in many cases, as archaeologists we need to find ways to distinguish the signal from the carrying substrate.

Thirdly, in a trading network, the flows of energy and information are often intertwined. What is at a certain point in time an outward flow of information (in the form of objects with a particular significance) for one partner in a trade or exchange, can be a resource for another partner (who cannot make the same objects). But after a while, once the receiving partner has mastered the information processing needed to produce these objects, these need no longer be imported, and the flows change when the second centre becomes a net exporter of such objects.

Fourthly, for an outward flow, the information processing gradient diminishes the farther one gets from the centre, while the value gradient for that same flow increases the farther away one gets, because the rarity of the high-information objects increases with distance from the centre. For the inward

[2] Whereas the latter flow is essentially dendritic (coming from all around, it has to reach all individuals in the society, albeit to a varying extent), the flow of information is not necessarily dendritic.

flow it is the reverse—raw materials are more common further from the centre, and gain in value the closer they come to the latter because there is more know-how to do something with them that can then be 'exported' as a high-value commodity.

## 14.6 INNOVATION

For a centre to function as such, that centre must succeed in maintaining the high information-processing potential that makes it attractive for its surroundings, notwithstanding the fact that this information-processing capacity spreads wider and wider (and can be retained, it must be remembered, by anyone given enough time to gather the know-how to do so). The only way to ensure that potential is for the centre to innovate continuously—the centre must at any time be 'ahead of the curve' in solving the challenges of the society. If that is no longer the case, people will lose interest in being part of the system's flows. While people are interested, one could say that they are to an extent 'aligned'—they participate, each in their own way, in the two flows and are therefore individually satisfied in the sense that they have the information available to procure for themselves the resources to satisfy their expectations (which are in turn a function of their information processing).

What enables the centre to keep innovating (improving its information-processing capacity)? In the centre there are more challenges, more knowledge, and more people to deal with these challenges. The interaction between those three, as we have seen above, augments information-processing capacity. That is further facilitated by the fact that in the centre the lines of communication between people are shorter, as they live closer together, and they can therefore exchange more information (channel capacity for signals is in part determined by channel length—long channels generate more noise and therefore the fidelity of the signals is reduced, and more exchanges can be carried out in less time as transport time is reduced).

Underpinning that dynamic is one that we know well in the modern world. Invention is usually (and certainly in prehistoric and early historic times) something that involves either single individuals, or very small teams. Hence, in its early stages it is related to a relatively small number of cognitive dimensions—it solves challenges that few people realize. As such, inventions become the focus of attention of much larger numbers of people, people see more uses for them, ways to slightly improve them, etc., and this in certain cases triggers an 'innovation cascade'—a string of further innovations, including new artefacts, new uses of existing artefacts, and new forms of behaviour and social and institutional organization. In this process, clearly, towns and cities are more successful than rural areas because of the greater number of

interactive individuals in such aggregations. That is corroborated by the fact that when scaling a number of urban systems of different sizes against respectively metrics of population, energy, and innovation, population scales linearly, energy sub-linearly, and innovation capacity super-linearly (Bettencourt et al. 2007).

## 14.7 THERE IS MORE TO NODES THAN MERE POSITION

Throughout this book, and in most of the archaeological literature on networks I am aware of, we seem to be dealing with 'flat' networks, or at least flat projections of networks, even though in human societies hierarchy is a very important structuring characteristic. In such networks, only the position of any particular node in the network is taken into account, and the network itself is viewed independent of the temporal dimensions that affect different interactions differently. That simplification explains that a couple of well-known phenomena in geography have not really found their way into our conceptualization of networks: site duration as a function of primacy, and site size as a function of centrality.

Primacy (being the first, or one of the first, established nodes in a network) offers the advantage of choice, and therefore in many cases the first settlement, for example, is located in a more resource-rich environment or at least an environment that has certain advantages over the environment of subsequent settlements. This is directly relevant for the size and life expectancy of such nodes. In the Rhone Valley, for example, the earliest Roman settlements proved (statistically) to be the wealthiest and to survive much longer than later ones. They also attracted the first roads, facilitating access for their products to market towns, etc., thereby augmenting their initial advantages even further (Archaeomedes 1998). The same effect of primacy is also highlighted in Renfrew and Level's application of the XTENT model to settlements on Malta and in other locations (1979). Hence we need to find ways to include the (relative) time of establishment of nodes into our understanding of network dynamics.

One cannot judge each node in a network by the same standards. As Sanders and Mathian demonstrated in our research in modern-day southern France (2000), the function(s) each node fulfils in a network is in part dependent on the proximity of other settlements. A settlement of a certain size will fulfil very different regional functions (and therefore have a different role in a network) if there are no other equal or larger settlements within a certain radius, than when there are such settlements. Hence in constructing the kinds of trade networks

many archaeologists do, they need to take proximity of other settlements into account in evaluating the roles of individual settlements, and this may also impact on centrality—in analysing settlement networks, some kind of weighing of site size should be included alongside centrality.

## 14.8 HIERARCHICAL NETWORKS

Both these phenomena can be included in network approaches if the networks are conceived as hierarchical rather than flat. White (2009) discusses the basics of such networks. In what follows, I will draw heavily upon his paper.

If a network consisting of a single kind or set of links is portrayed as a graph, consisting of nodes and directed or bi-directed edges between them, the generic form of hierarchy is described as a *directed asymmetric graph* (or *dag*) where every edge is directed (asymmetric, non-reciprocal—or, as a refinement, at least between different levels) and there are no directed cycles. A theorem for such *dag* structures is that the nodes can be ordered in a minimal number of levels so that every directed edge orients in a consistent direction. If a network is characterized by both the *dag* and a pyramidal structure with fewer nodes at the top and more toward the bottom, then it defines a *hierarchy*.[3] The usual conception of such a hierarchy is that those (fewer) nodes at the 'top' have greater power, prestige, income, information, expertise, etc. Such *dominance hierarchies* appear in many situations as one of several basic and often co-occurring forms of hierarchy. In our case, we can conceive of the networks channelling information-processing capacity from the centre to the periphery as such dominance hierarchies. In network terms, nodes in such a hierarchy dominate others in a-cyclic directed chains; that is, *dags*, often with additional structural properties, such as density of links between different pairs of levels.

Another organizational form based on acyclic directed chains is the *reverse hierarchy*. Such hierarchies seem to be a crucial part of human culture (Henrich 2001; Henrich et al. 2005). They might in our case be thought of as the hierarchies in which energy and other resources move from the periphery to the centre of the system.

Taking this approach, we can conceptualize networks and the dynamics in them simultaneously in terms of three fundamental characteristics: (1) their *structure* (e.g. *dag*, pyramidal), (2) their *routes of traversal* through which (directed or two-way) flows of information, materials, or energies are channelled, and (3) the *specific attributes of individual nodes and of the links*

[3] N.B: Not all *dag* structures have this property.

*between them*. For a network in which nodes *transfer* resources to others, for example, transferring may be any of a whole array of possibilities, from trade and exchange to taxes and tithes. In addition, if one relation forms a pyramidal *dag* hierarchy, it may be complemented by other relationships, including *dag* hierarchies of the same or the reverse kind. The alignment of *dag* hierarchies and flows of various kinds then become research questions.

Ambiguities in the ways that hierarchies are constructed are a common source of instability in economic, social, and political systems. The complexities of the interactions inflected by competing hierarchical structures, and the many direct and indirect traversal patterns that they allow, make prediction of trajectories difficult. These are complex nonlinear systems, and the best we can do probably is to model how their structural and flow properties provide an understanding of their dynamical instabilities.

## 14.9 MULTI-NETS

Now let us draw some other consequences from the change in perspective I have argued for at the beginning of this chapter—from an '*ex post*' perspective to an '*ex ante*' perspective. Clearly, from such a perspective, we must look at how networks grow, rather than analyse them once they are full-grown. We must look at the *agentive quality* of the network, as Rivers, Knappett, and Evans have called it in their contribution to this volume. For our understanding of what happened in the past, it is not enough to reconstruct a series of 'stills' and interpolate what happened between them—we have to conceive of the dynamics of interaction that drove the emergence of the phenomena for which we observe the traces in the archaeological record. And that requires, again, that we create a 'tool for thought'—a model of how this might happen that is drawn from anthropological or historical case studies, or even from observations made in the present.

At the macro level, I think we can fairly and safely postulate that the initial network from which all other social networks emerged is a kinship network. In small-scale societies, presumably, all transactions occurred between people who were, in one way or other, related to each other by kinship. But as the number of people involved in a 'dissipative flow structure' of the kind outlined above grew, in parallel with the expansion of the 'cognitive sphere' (the total know-how and knowledge they had available to them) that bound them together, other kinds of relationships would emerge. Some of these would cover multiple activities, such as '*compadrazgo*',—extended (artificial) kinship—or feudal or client relationships (in which one party provides energy to the other in exchange for protection and support in times of need), while others would be directly related to a particular activity or function, such as trade or industrial relationships. The

important thing to realize here is that each of these kinds of relationships will have created other networks, which were not coterminous with each other. From a single network, a complex set of multiple networks would emerge over time that bound the members of the society together in a true web of functionally different relationships—the denser the more complex the society. This process is very inspiringly described by Padgett for early Renaissance Florence (Padgett 1997; Padgett and McLean 2006; Padgett and McLean 2011), where networks of spatial relationships, business relationships, kinship relationships, and other kinds of relationships emerged together with the different kinds of transactions and methods of the banking industry.

Ideally, therefore, one would want to identify the emergence of such multi-nets (cf. White 2009) also in archaeological contexts. In favorable circumstances, this could be initiated by using a GIS program to 'decompose' a landscape in maps that reflect the different economic activities that a particular society practised—agriculture, herding, hunting, fishing, local trade, pottery-making and trading, long-distance trade in precious objects, etc., and locating on these maps the networks that involve each of these activities. That would yield a much better approximation of the role of geography in the interactions within and between societies than merely calculating various kinds of 'centrality' to identify the core locations in a network.

But the geographical aspect of such multi-nets is not the only relevant one. The interactions occurring in the different networks constituting a multi-net generally occur at different timescales. Indeed, Glance and Huberman (1997) demonstrate that that is an essential characteristic of networks that operate close to optimality. In everyday life that can be observed by mapping how the different temporal rhythms associated with different activities interact. At first sight, once fields have been cleared, agriculture operates on an annual or seasonal cycle, whereas herding involves a multi-annual one that is determined by the life cycle of the animals involved. But in reality each of these activities involves multiple rhythms that, together, both separate subsets of the multi-net and render these subsets coherent (Schippers 1986). To truly understand the dynamics in such a network, one thus needs to be able to identify and articulate the different subsets involved.

White suggests (2009) that the best way to understand such complex multi-nets is by measuring structural cohesion and identifying more precise measures of segmentation versus cross-cutting integration in overlapping relational structures. The first step is to study which relations are correlated across pairs of people. Clustered relations with similar kinds of content transmission can be identified as those that form interactive communities. Once those community-forming sets of relations are identified, they can be analysed together by simple aggregation, and these aggregate networks can be analysed for boundaries of structural cohesion. The communities may overlap, forming cross-cutting integration, or may segregate, forming segmentary structures.

Recall that *structure* and *traversal* are the two fundamental kinds of properties that combine in networks. Menger's multi-connectivity theorem (Moody and White 2003) provides a way to define cohesive network structures by connecting the *cohesive structures* that occur in networks with the capacities for multiple independent *routes of traversal* within these very same structures.

A *component* of a network is a largest possible connected structure, but it is potentially vulnerable to disconnection by removal of a single node. A *bi-component* is a largest possible connected structure that cannot be internally disconnected by single-node removal. Components, bi-components, tri-components, and *k*-components (vulnerable to disconnection only by removal of *k* or more nodes), are instances of the general concept of *structural cohesion* but differ in level of cohesion. Menger's theorem is that the extent of *structural cohesion* is equivalent to the largest sub-networks with at least *k* redundant pathways between every pair of nodes (i.e. all pairs have a minimum level *k* of cohesive *traversal* between them). The structural and traversal aspects of cohesion thus unite to form a single concept (the *k*-component) with two aspects: (a) structural cohesion as invulnerability to node removal that will disconnect the group (structurally), and (b) ease of (traversal) communication and transport within.

If we identify *k*-components in social networks as sub-graphs of nodes and the edges between them, we can also call them by the term 'structural cohesion *groups*'. Structural cohesion groups have obvious benefits for cooperation and collaboration, and, if they can scale up with little or no institutional cost or additional cost per participant, we should find that they are implicated in a wide variety of contexts, including social stability and the formation of social units on the one hand, and in innovation, social movements, competitive rivalry, and conflict on the other.

Structural cohesion groups can grow very large while minimizing the possibility that parts of the network will disconnect with the exit of a limited number of members. In this kind of structure, a sub-network can add nodes and links to strengthen traversability within and to reinforce immunity to disconnection from without. It is that capacity that has enabled large populations to interact stably over considerable periods of time, for example in some of the historical empires or even in the current wave of globalization.

## 14.10 SUMMARY AND CONCLUSION

In these few pages, rather than present an original contribution to the 'network' approach, I have chosen to make some suggestions about two main topics. First of all, about the change in focus that archaeology is currently undergoing, from the study of 'being' to that of 'becoming', from a static or

equilibrium approach to a dynamic perspective, and from knowing the present to understanding the future. Network approaches can and should play a very important role in that development. Next, I have introduced a dynamical perspective on societies as 'dissipative flow structures' that bootstrap themselves in interaction between knowledge, challenges, and people so as to accumulate more and more of each of these. These flow structures are driven by a feedback loop between organization (information processing) and resources; these flows are likely to be differently configured but the information processing networks determine the channels for the flows of resources.

Such flow structures are efficiently studied in network terms providing one has a model of their dynamics in mind, so that the network approach is not only used analytically, but also to improve our understanding of the dynamics that are responsible for the networks. For one, both the organization and the resource networks should be studied together—they are not identical but woven together in different ways, and analytical techniques will have to be developed to study their interactions. These techniques will, among other things, have to be able to distinguish and separate flows of signals from flows of their material- or energetic-carrying substrates. But they will also have to enable us to study the interaction of value creation and value consumption across a core–periphery system. And finally, they will have to be able to incorporate the study of invention and innovation as an important structuring element of the societies we are studying. And finally, our approaches will have to be able to deal with the emergence of (functional) multi-nets out of a single (kinship) network, and to allow us to understand the dynamics of such multi-nets, their components, and the ways these components are linked to ensure their overall stability.

All this implies that archaeologists and other practitioners of the historical disciplines have their work cut out for them—so far they have only explored and exploited the tip of the iceberg of the network perspective on society. But if the signs do not betray me, that exploration promises to be a fascinating and very rewarding trip that may bring our discipline much closer to a truly dynamic understanding of past societies.

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